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MOBILITY ANALYSIS OF IFV TASK FORCE ALTERNATIVES.(U)
JUL 78 A W CRISWELL, L E MARTIN

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A mobility analysis of several conceptual Infantry Fighting Vehicles and several existing tracked vehicles is conducted. Both on-road and cross-country mobility are modeled along with acceleration in a variety of terrain conditions. Transportability of the conceptual vehicles is examined for the road, rail and air modes of movement.

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MOBILITY ANALYSIS OF IFV TASK FORCE ALTERNATIVES

I. INTRODUCTION

This report contains the results of an evaluation of the mobility of several concepts for an Infantry Fighting Vehicle (IFV). These concepts were developed by the US Army Tank Automotive Research and Development Command (TARADCOM) for the IFV TASK FORCE.

The evaluation examines mobility on the strategic, operational and tactical levels and provides a comparison of the concept vehicles' performance with several other tracked vehicles. This evaluation effort was conducted at the request of the IFV TASK FORCE.

II. VEHICLE CHARACTERISTICS

The IFV concepts considered in this evaluation are listed in Table 1. The detailed data used for mobility modeling of these concept vehicles are listed in Appendix A. Because of a lack of adequate test data to estimate the performance provided by the planned improvements to the MICV, XM723 DT-II suspension, its performance, as noted in Table 1, was simulated by assuming a ride limited speed equal to that achieved with the current XM1 suspension. Figure 1 places XM1 suspension performance in perspective with regard to the performance obtained by the MICV, XM723, in DT-II testing (prior to improvement). It should be noted that the existing test results for an improved MICV suspension [(1)*] do demonstrate a high performance capability, but also indicate serious durability problems for suspension components, in particular the shock absorbers.

Table 2 provides a further general comparison of the IFV TASK FORCE vehicles and the comparison tracked vehicles on the basis of general mobility characteristics.

[(*)] Numbers denote references listed on page 49 of this report.

Table 1 IFV Task Force Vehicles

Vehicle Name	General Description	TARADCOM DWG No.	Gross Vehicle Weight, Tons	Engine HP	Type of Suspension	Remarks
M113A1	Armored Personnel Carrier, .50 cal MG	-	12	215	STD. M113A1	STD. Infantry Payload
IFV #1	XM723, MICV, TBAT Turret, MICV Protection levels	-	23.5	500	Improved MICV Type	Assumed to provide ride speed limit characteristics equivalent to XM-1
IFV #2	XM1 Chassis extended, TBAT Turret, XM1 Protection levels	LK10744	65	1500	XM1 Type	
IFV #3	XM1 Chassis, TBAT Turret, Reduced XM1 Protection Levels	LK10744	59	1500	XM1 Type	
IFV #4	XM1 Chassis, TBAT POD, XM1 Protection levels	LK10731	55	1500	XM1 Type	
IFV #5	XM1 Chassis, TBAT Turret, MICV Protection levels	LK10744	32.8	1500	Improved MICV Type	Assumed to provide ride speed limit characteristics equivalent to XM-1
IFV #6	XM1 Chassis, 75mm Gun, XM1 Protection Levels	LK10782	59	1500	XM1 Type	Mobility Characteristics Same as IFV #3

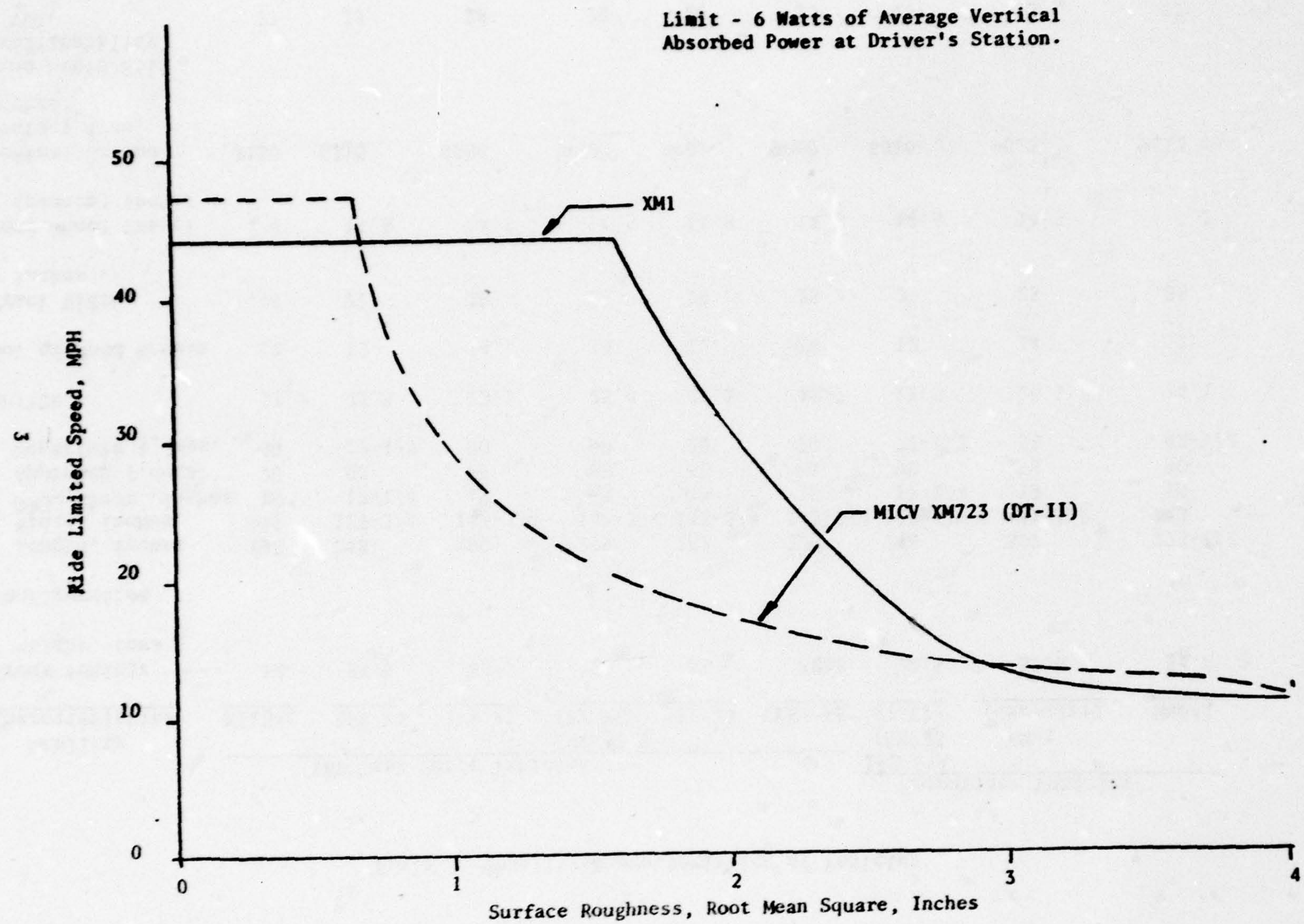

Figure 1. Ride Performance Comparison

Table 2 Mobility Characteristics of Vehicles

	IFV Task Force Vehicles						Comparison Vehicles		
Mobility Characteristics	M113A1	IFV #1	IFV #2	IFV #3 & IFV #6	IFV #4	IFV #5	IFV #1A (XM723 DT-II)	XM-1 (Chrysler)	M60A1
Gross Vehicle Weight, tons	12	23.5	65	59	55	32.8	23.5	57.5	54.8
Configuration									
Length, inches	192	248	299	299	287	299	248	307	273-1/2
Width, inches	105	127-3/4	143-3/4	143-3/4	143-3/4	143-3/4	127-3/4	141-1/2	143
Grd. Clear., inches	16	17-1/4	19	19	19	19	17-1/4	19	18
Approach ∢, degs.	70	90	65	65	65	65	90	58	90
Departure ∢, degs.	40	77-1/2	90	90	90	90	77-1/2	38	42-1/2
HP/TON	17.9	21.3	23.1	25.4	27.3	45.7	21.3	26.1	14.1
No. of Road Wheels	10	12	14	14	12	14	12	14	12
Track Width, inches	15	21	25	25	25	25	21	25	28
Road Wheel Travel (Bounce) inches	6	14.5	14.5	14.5	14.5	14.5	14.5	14.5	7.2
Nominal Ground Contact Area, inches^2	3150	6316	9000	9000	9000	9000	6316	9025	9353
Fine Grain Soil Trafficability									
VCI_1	17	13	28	26	26	13	13	25	22
VCI_{50}	39	32	63	59	60	31	32	58	51

III. Methodologies

A. The Army Mobility Model

This model considers vehicle performance in both areal and linear type terrain features. The areal mobility prediction part of the Army Mobility Model[2] (which is the only portion used in the IFV evaluation) is shown schematically in Figure 2. The fundamental operation of this model is as follows. Detailed areal terrain data are collected from existing terrain data sources such as topographical maps, air photos, terrain studies, agricultural data, and soil maps. Where possible these data sources are supplemented by actual field surveys. All these data sources are then used to develop a series of individual maps of the area being considered for each of the terrain factors shown in Figure 2.

The terrain input processor accepts these maps and overlays them to define areas in which the terrain is homogeneous with respect to all of the terrain factors simultaneously. The result of this process is an areal terrain unit map as shown, where unit number 98 might reflect an area where the slopes are always between 5 and 10 percent and the soil strength in the wet season is always between 40 and 60 remolded cone index, etc. Associated with each map unit number is a range of values for each of the 13 terrain factors. For example areal terrain unit number 14 may have the following detail factor value listing: 1 5 3 9 4 3 5 1 1 3 1 5 4 3 3 2 1 1 3.

Where the detail factor values are as follows:

	Factor Value	Description
1.	1	Soil type fine grain
2.	5	Soil strength (wet) 61 to 100 remolded cone index (RCI)
3.	3	Slope 5.1% to 10%
4.	9	Obstacle approach angle 149.1° to 158°
5.	4	Obstacle vertical height 36 to 45 cm
6.	3	Obstacle base width 61 to 90 cm

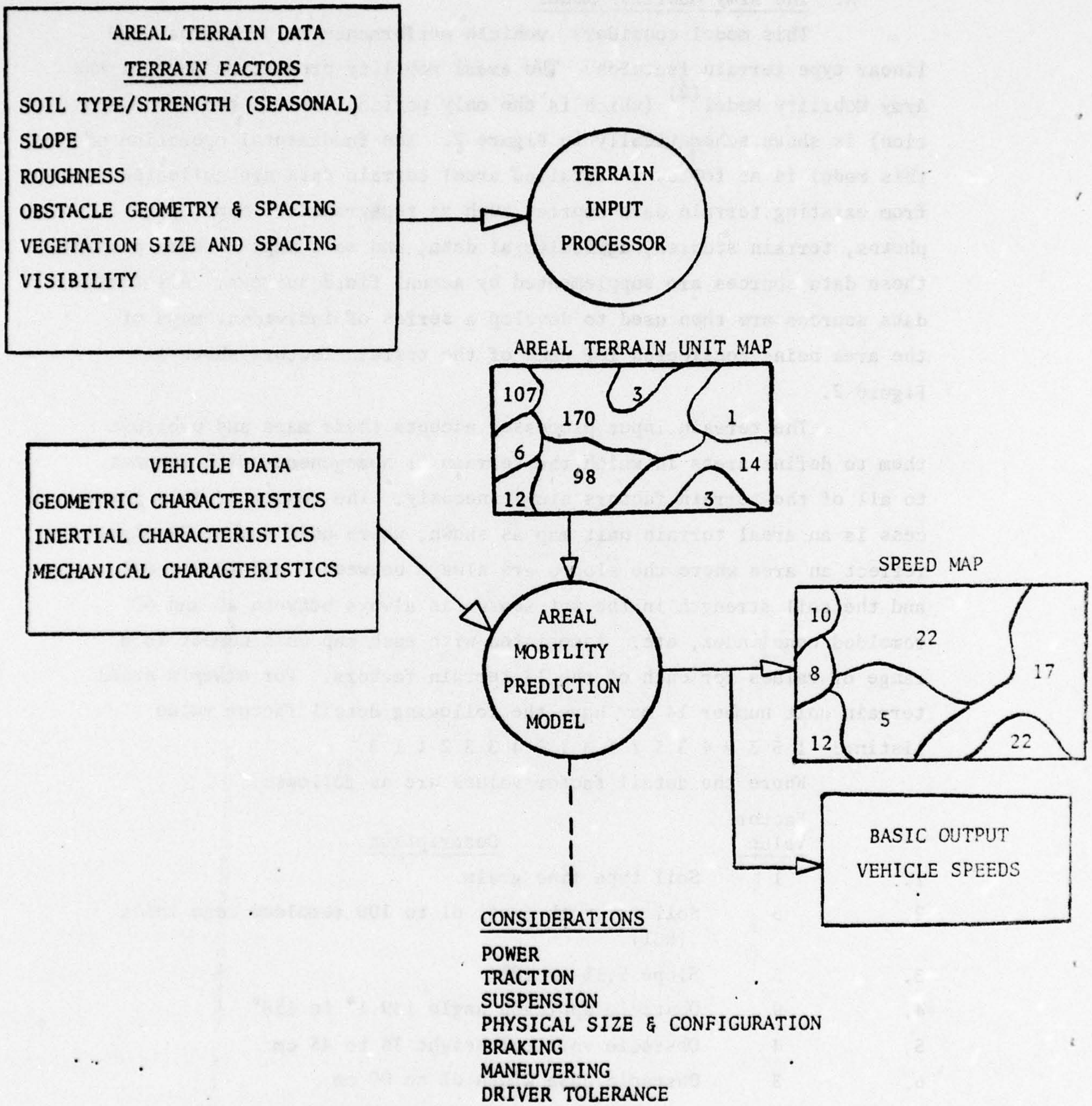

Figure 2 The Army Mobility Model (Areal Mobility Prediction)

7.	5	Obstacle length 3.1 to 6.0 m	
8.	1	Obstacle spacing bare 60m	
9.	1	Obstacle spacing type random	
10.	3	Surface roughness 2.6 to 3.5 RMS in.	
11./12.		Spacing of vegetation stems equal to or greater than	
	1	0 cm dia.	bare (> 100m)
	5	2.5 cm dia.	5.6 - 8m
	4	6.0 cm dia.	8.1 - 11m
	3	10.0 cm dia.	11.1 - 20m
	3	14.0 cm dia.	11.1 - 20m
	2	18.0 cm dia.	> 20m
	1	22.0 cm dia.	Bare (> 100m)
	1	25.0 cm dia.	Bare (> 100m)
13.	3	Visibility range	12.1 - 24m

Areal terrain unit maps for use with the areal model are developed by the US Army Engineer Waterways Experiment Station (WES). The locations of the areas selected for use in the IFV evaluation are shown in Figure 3. The combined areas in West Germany consist of approximately 59 square kilometers and 235 areal terrain units. The Jordan area consists of approximately 155 square kilometers and 221 areal terrain units. Both of these areas have been used by AMSAA in previous mobility evaluations for other combat vehicles. Analysis of these two areas shows the distributions listed in Table 3. As shown, each area provides different combinations and magnitudes of terrain characteristics that will affect vehicle performance in different manners.

The model requires a maximum of seventy-six vehicle characteristic inputs. These range from vehicle size and weight to details of its power train and suspension components. With these data the various mathematical submodels of the overall model predict vehicle performance in the terrain factor values established for each map unit. The data used for the IFV concepts examined in this evaluation are listed in Appendix A.

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*The 1971 edition of the model[2] was used in this evaluation.

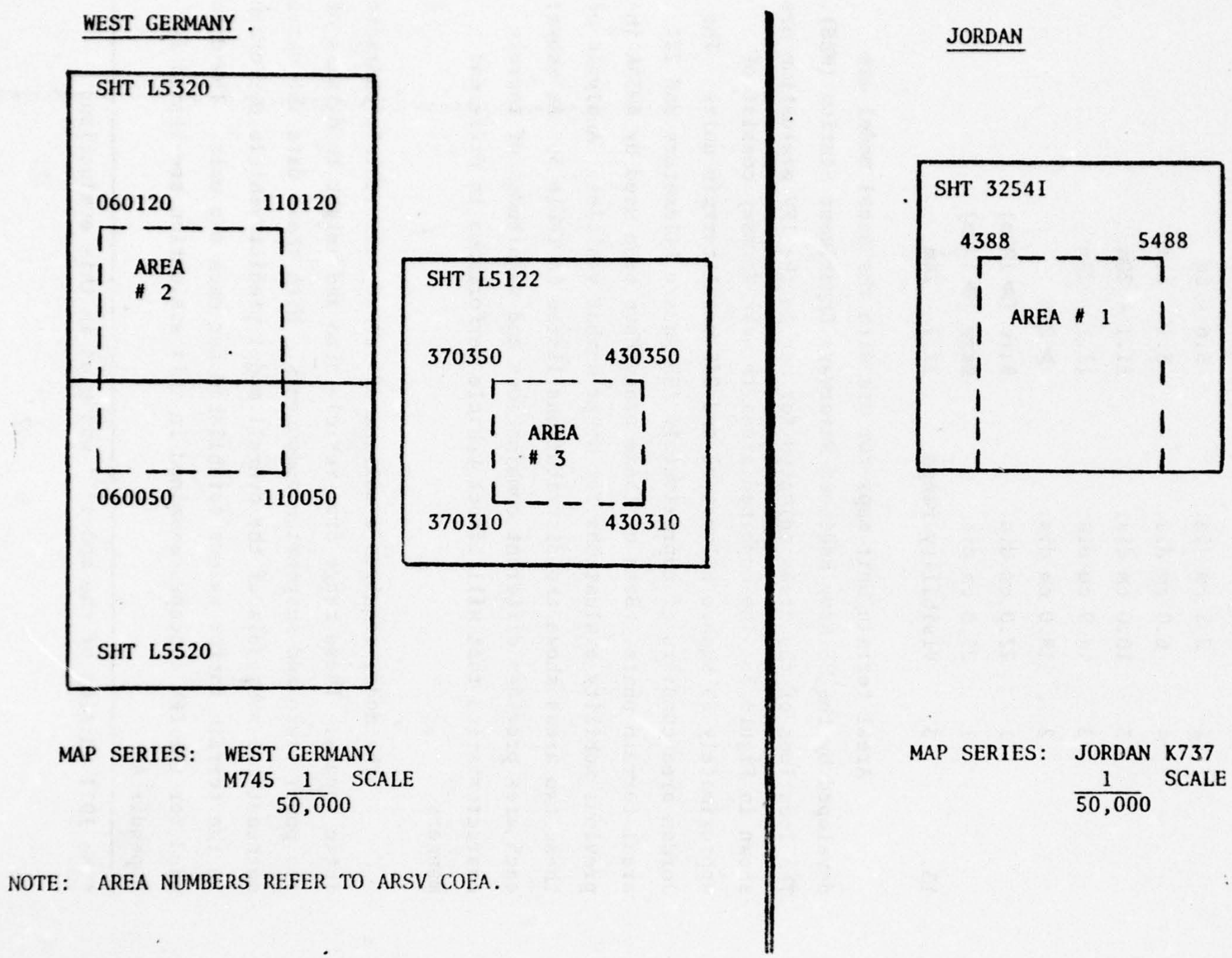

Figure 3 Terrain Area Locations Used in IFV Evaluation

Table 3 Distribution of Terrain Factors

Terrain Factor	West Germany Area #2	West Germany Area #3	Jordan Area #1
Soil Type			
Fine Grain	100%Δ	100%Δ	94.6%Δ
Coarse Grain	-	-	5.4
Wet Season Soil Strength, (RCI, CI)			
>281	2.7	7.6	2.3
101-160	18.6	30.7	5.4 (CI)
61-100	78.0	-	92.3
41- 60	.7	61.8	-
Slope, %			
0- 2	4.6	7.6	98.2
2.1- 5	9.9	6.8	1.6
5.1-10	62.0	41.9	-
10.1-20	23.4	36.9	-
>20	-	6.8	-
Surface Roughness, RMS inches			
0- .6	2.7	7.6	2.5
.61- .8	13.8	11.4	9.7
.81-1.2	5.6	12.1	10.2
1.21-1.6	45.7	18.3	27.0
1.61-2.2	12.3	33.3	24.2
2.21-3.2	11.0	11.2	9.5
>3.21	8.9	6.0	16.9
Obstacle Vertical Height, inches			
0-10	85.1	67.3	30.8
10.1-18	7.8	18.1	29.9
18.1-23.6	.5	1.8	22.8
23.7-33.5	3.3	7.5	14.3
>33.5	3.4	-	2.2

Δ - Percent of area.

Submodels consider vehicle performance in the following manner:

Terrain Factors Considered	Vehicle Performance Predicted
Soil type, Soil strength, Slope	Tractive and resistance force throughout speed range.
Terrain roughness	Ride limited speed.
Obstacles	Hangup, traction, dynamic loading, acceleration and braking between obstacles.
Vegetation	Traction for overriding, and vehicle size for maneuvering between trees. Driver visibility.

For a given area/map unit the speed results of each of these submodels are compared for uphill, downhill, and level slope conditions; the limiting value is selected for each condition, and the three limiting values are averaged to provide the vehicle's estimated best speed in that map unit. In considering the vegetation factor the model examines various strategies of maneuvering around certain size trees and overriding others to obtain the best vehicle speed. Such terrain factors as soil strength and slope naturally interact with others so are considered simultaneously. For example, a vehicle on a soft soil slope will have less tractive force available to climb an obstacle or override a tree than it would on a level hard surface because some of its tractive force capability is used in overcoming the soft soil motion resistance and the grade resistance. The basic speed output of the model can be used to develop a speed map as shown in Figure 2.

B. Speed Model

This model is a portion of the Vehicle/Road Compatibility Analysis and Modification System (VRCAMS).[3] It was used in this evaluation to assess the on-road capability of the IFV and comparison vehicles. The model is similar in concept to the Army Mobility Model discussed previously. The factors involved in the road unit characterization, the generalized vehicle parameters, and the model output are shown in Figure 4. Road nets have been described by the US Army Engineer Waterways Experiment Station for West Germany, Thailand and Yuma. These descriptions have been used as input to generate average speeds by road class for the vehicles of interest. Three classes of road are identified and are defined as follows:

Class 1 - Primary: Surfaced all weather roads, two lanes or more.

Class 2 - Secondary: The balance of all weather roads, generally unpaved but improved, plus paved roads less than two lanes wide.

Class 3 - Trails: Unimproved and fair weather roads and trails of at least one vehicle width.

The terrain factors assigned to these classes of roads are shown in Table 4.

The total length of each type of road used in this evaluation were the following:

	Class 1 Paved	Class 2 Secondary	Class 3 Trails
West Germany	104 miles	82 miles	589 miles
Yuma	84	87	204
Thailand	70	67	277
TOTAL	258	236	1070

C. AMSAA Acceleration Model

This model is based on an earlier acceleration routine developed at TARADCOM. It computes acceleration for both wheeled and tracked vehicles on fine grain and coarse grain soil, and on paved or secondary roads, and includes the resistance due to surface conditions and grade. The model contains empirical expressions for the power lost in accelerating the rotating parts in the vehicle drive train as well

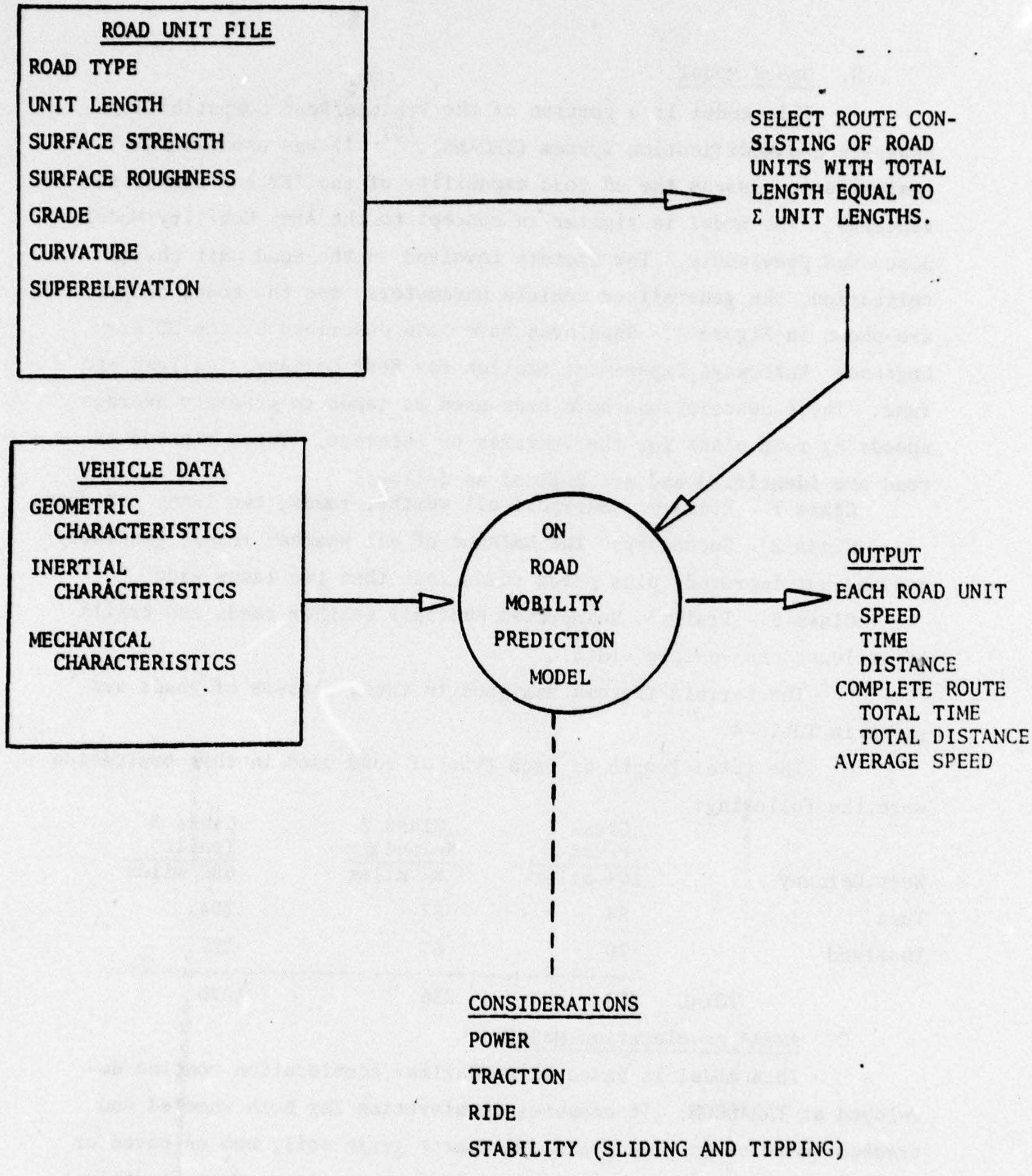

Figure 4 ON-Road Mobility Prediction Model

Table 4 Road Unit Terrain Factors

TERRAIN FACTOR	FACTOR CLASSES 1	2	3	4	5	6	7	8	9	10	11
Type of Road Surface	Unpaved[0] Fine Grain Soil	Unpaved[0] Coarse Grain Soil	Paved[Δ]	Secondary[ø] (improved)							
Surface Strength RCI or CI	> 280	221-280	161-220	101-160	61-100	60-41	33-40	26-32	17-25	11-16	0-10
Surface Roughness RMS inches	0-.4	.5-1.5	1.6-2.5	2.6-3.5	3.6-4.5	4.6-5.5	5.6-6.5	6.6-7.5	>7.6		
Grade (percent slope)	0-2	2.1-4	4.1-6	6.1-8	8.1-10	10.1-15	15.1-20	20.1-30	30.1-40	40.1-60	60.1-80
Curvature (degrees)	0-2	2.1-4	4.1-6	6.1-8	8.1-10	10.1-15	15.1-20	20.1-30	30.1-40	40.1-60	60.1-80
Superelevation[*] ft/ft											
Paved Road	0	.05	.08	.1	.1	.1	.1	.1	.1	.1	.1
Secondary Road	.04	.04	.04	.05	.07	.09	.1	.1	.1	.1	.1

0 - Unpaved denotes trails resistance per surface strength (factor #2)

Δ - For paved roads - vehicle measured paved surface rolling resistance lbs/ton.

ø - Improved surfaces - paved surface rolling resistance + 20#/ton

* - Applies to only paved and secondary roads - based on design speed of 50 mph for paved roads/35 mph for secondary roads, and degree of curvature per TM 5-330.

as for the air resistance encountered. The model output is velocity and distance as a function of time.

IV. RESULTS

A. Strategic Mobility

Strategic mobility as considered in this evaluation is defined as the ease of transport of the vehicle to its operational areas. The ease of transport of the IFV concepts is primarily a function of their overall dimensions and weights. In general, strategic mobility involves either movement by truck, ship, train or aircraft over long distances.

The current requirements for the MICV dictate transport over US and foreign railways without requiring disassembly. Reference 4, Figure 2-2, page 2-7 and Figure 2-3, page 2-8 gives dimensioned outline diagrams for railway lading clearances. These clearances are determined by tunnels, platforms, electric and telephone poles, bridges and wayside structures.

For the US railroads a maximum width of 128 inches is available up to a height of 115 inches above the car floor. Foreign railroads provide a maximum clearances of 124 inches for a height up to 74 inches. As shown in Table 5, except for IFV #1 and #1A, the existing XM723 IFV chassis, all concepts have widths that exceed the maximum allowable widths for both US and foreign railroad operations. The IFV #1 and #1A however, will fit within these clearances with the reduced width shown in Table 5. When using the width dictated by the no disassembly requirement, these two vehicles can be transported on US railways with a 1/8" clearance and are not transportable on foreign railways due to a 1-7/8" interference.

For road transport on the M747 HET trailer all IFV concepts, except IFV #1 and #1A, have reducible widths greater than the 120-inch trailer platform width. All vehicles have widths equal or less than trailer overall width of 137 inches as determined by the outside of the trailer tires. The HET trailer loading platform length of 317 inches will allow for transport of only one concept vehicle at a time, however, the transport weight of IFV #2 exceeds the rated payload of the trailer by 4 tons. This overload may adversely affect the durability of the trailer tires and suspension components.

Table 5 Transportability Data

Vehicle	Transport Ø Weight, Tons	No. of Roadwheels	Dimensions, inches Length	Reducible* Width	Reducible* Height	Average Roadwheel Load, lbs.	Average Contact Pressure, psi
IFV #1 & #1A	22.5	12	248	112-3/4	107	3750	130.6
IFV #2	64	14	299	137	104	9143	145.1
IFV #3 & #6	58	14	299	136	102 - #6 104 - #3	8286	131.5
IFV #4	54	12	287	137	116	9000	142.9
IFV #5	31.8	14	299	137	104	4543	72.1

Ø - Transport weight equals GVW less 2000 lbs for personnel.

* - These data were estimated from drawings.

Track shoe areas: IFV #1 & 1A = 28.7 inches^2
IFV #2 thru #6 = 63.0 inches^2

The air transportability of the IFV concept vehicles was examined based upon the requirements established for the XM723. As stated in section 3.2.9 of Reference 5, the vehicle shall be transportable in both the C-141A and C-5A type aircraft. To determine whether the requirements were met, the three following criteria were considered.

1. The aircraft design payload capability.
2. The aircraft cargo compartment dimensions.
3. The structural capacity of the aircraft cargo compartment floor.

The cargo compartment of the C-141A is 123 inches wide and 109 inches high with a design payload capability of 68,000 pounds based on maximum zero fuel weight. Referring to Table 5, the transport weights of IFV #2, IFV #3, IFV #4, and IFV #6 exceed the payload capability and IFV #5 is too wide. IFV #1 and IFV #1A, the existing XM723 IFV chassis, were investigated further to determine their transportability in the C-141A. Using Figure 4-8, Reference 6, the maximum allowable floor contact pressure on the treadways is 50 psi and from Table 5 the contact pressure of these vehicles is 130.6 psi. This dictates the use of shoring to further distribute the weight. Referring to Figure 4-12, Reference 6, the required shoring thickness is 1.84 inches. Using the next size stock lumber, a 3-inch nominal thickness plank is required to produce a dressed thickness of 2-5/8 inches. When this is added to the vehicle height of 107 inches, see Table 5, the total vehicle height exceeds the cargo compartment height of the aircraft.

The cargo compartment of the C-5A aircraft is 228 inches wide and 162 inches high with a design payload capability of 208,000 pounds based on maximum zero fuel weight. Again referring to Table 5, all of the concept vehicles comply with the three criteria examined with the addition of shoring to increase the load distribution area on the aircraft floor. Taking into account only the design payload of the aircraft as opposed to vehicle weight, it was determined that IFV #2, IFV #3, IFV #4, and IFV #6 will be limited to one vehicle per aircraft. Table 6 provides a summary of the transportability analysis results.

Table 6 Summary of Transportability Analysis

Configuration	Railways	Trucks Δ	Air: C-141A	Air: C-5A
M113A1	OK	OK	OK	OK
IFV #1 & IFV #1A	OK on US Too wide for Foreign		Excessive Height*	
IFV #2		Excessive Weight	Excessive Weight	
IFV #3				
IFV #4	Too Wide			
IFV #5		OK	Excessive Width	
IFV #6				
M60A1			Excessive Weight	
XM-1				

* - With Shoring
Δ - Using M747 Trailer

B. Operational Mobility

The evaluation here is directed toward mobility performance areas associated with movement within the operational areas and forward to the point of engagement or line of deployment. Movement can be characterized as being over reasonably long distances with good opportunity for choice in selecting the more trafficable terrain.

On-road speed performance of the IFV concepts and the comparison vehicles will be considered first. Table 7 lists the output of the Speed Model, by road type, for sample road nets in West Germany, Yuma and Thailand. These predicted vehicle speeds represent maximum vehicle capability over the road types and lengths specified for each area. The term "average speed" means that maximum speeds over the variety of road conditions occurring in each type of road have been averaged. Furthermore, these speeds depict the movement of a single vehicle and involve none of the constraints of convoy or unit movement.

As would be expected all the IFV concepts show faster speeds than either the M113A1 or M60A1 vehicles. The use of an XM1 type suspension in the existing XM723, IFV #1, indicates some speed improvement on secondary roads and trails as indicated by results shown for IFV #1 versus IFV #1A.

Among the IFV concepts employing the XM1 power train and suspension, IFV #5, the lightest weight concept, is predicted to have the best speed performance. All IFV concepts, IFV #2 thru IFV #6, have predicted speed capabilities near or slightly exceeding those of the XM1 tank and greater than those of the current M60A1 main battle tank. Even the existing IFV, the XM723 (IFV #1A), exceeds the M60A1 in predicted speed performance.

The final examination in the area of operational mobility is the cumulative average speed profile generated using the Army Mobility Model. Comparisons of these results are shown in Figures 5 through

Table 7 Predicted Road Performance

	Average Speed, mph								
	West Germany			Yuma			Thailand		
Vehicle	Paved Roads	Secondary Roads	Trails	Paved Roads	Secondary Roads	Trails	Paved Roads	Secondary Roads	Trails
M113A1	34.3	25.0	14.3	41.4	27.2	14.2	41.7	34.3	15.2
IFV #1	39.9	30.7	21.0	46.5	37.2	21.7	46.8	37.5	29.1
IFV #1A	39.9	29.5	18.7	46.5	31.7	18.2	46.8	35.4	19.7
IFV #2	39.4	34.6	21.8	43.1	42.1	23.4	43.8	43.0	28.8
IFV #3 & #6	40.7	36.6	22.3	43.3	43.0	24.6	43.9	43.7	28.8
IFV #4	41.7	37.8	22.8	43.5	43.2	26.1	43.9	43.7	28.8
IFV #5	44.0	43.5	24.3	44.0	44.0	28.4	44.0	44.0	28.8
M60A1	23.9	18.9	14.1	27.2	23.3	13.9	27.3	23.6	17.1
XM1	41.1	37.0	22.5	43.4	43.1	25.2	43.9	43.9	28.8

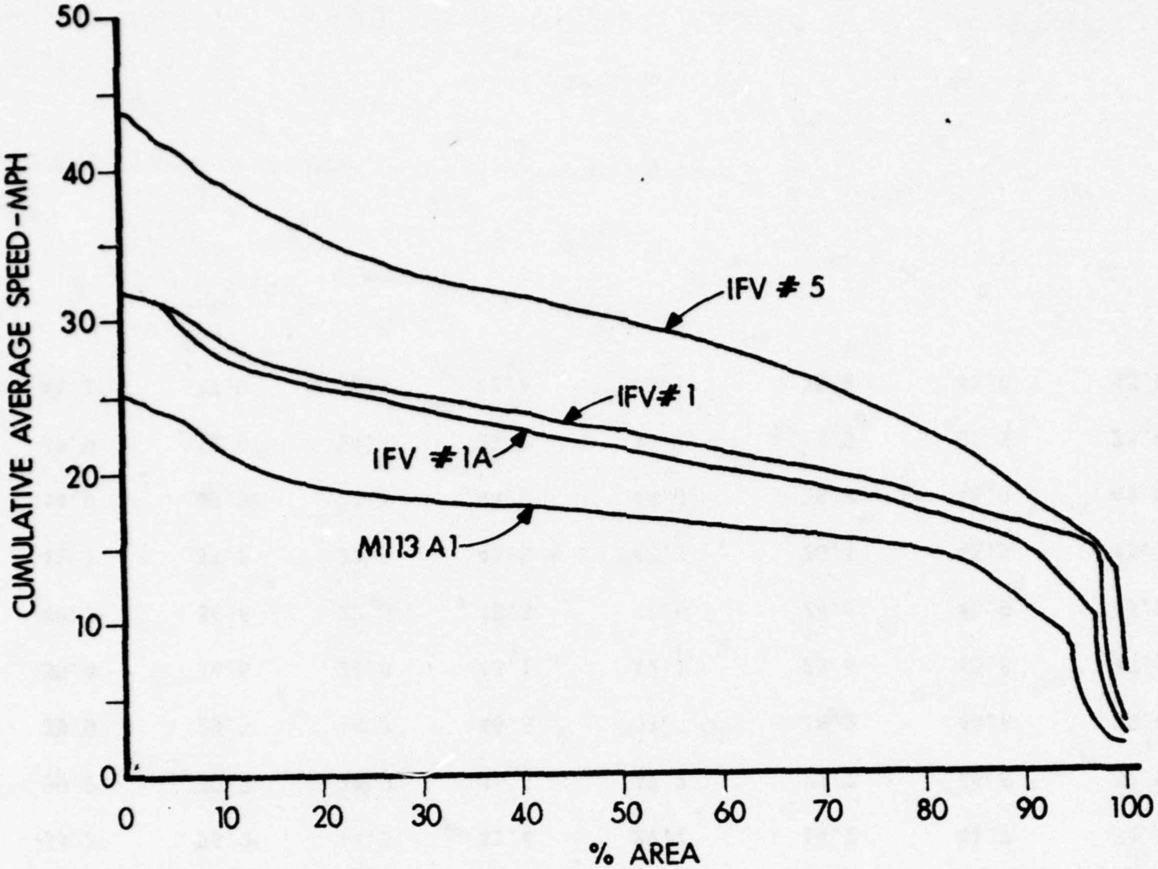

Figure 5. Vehicle Performance in West Germany.

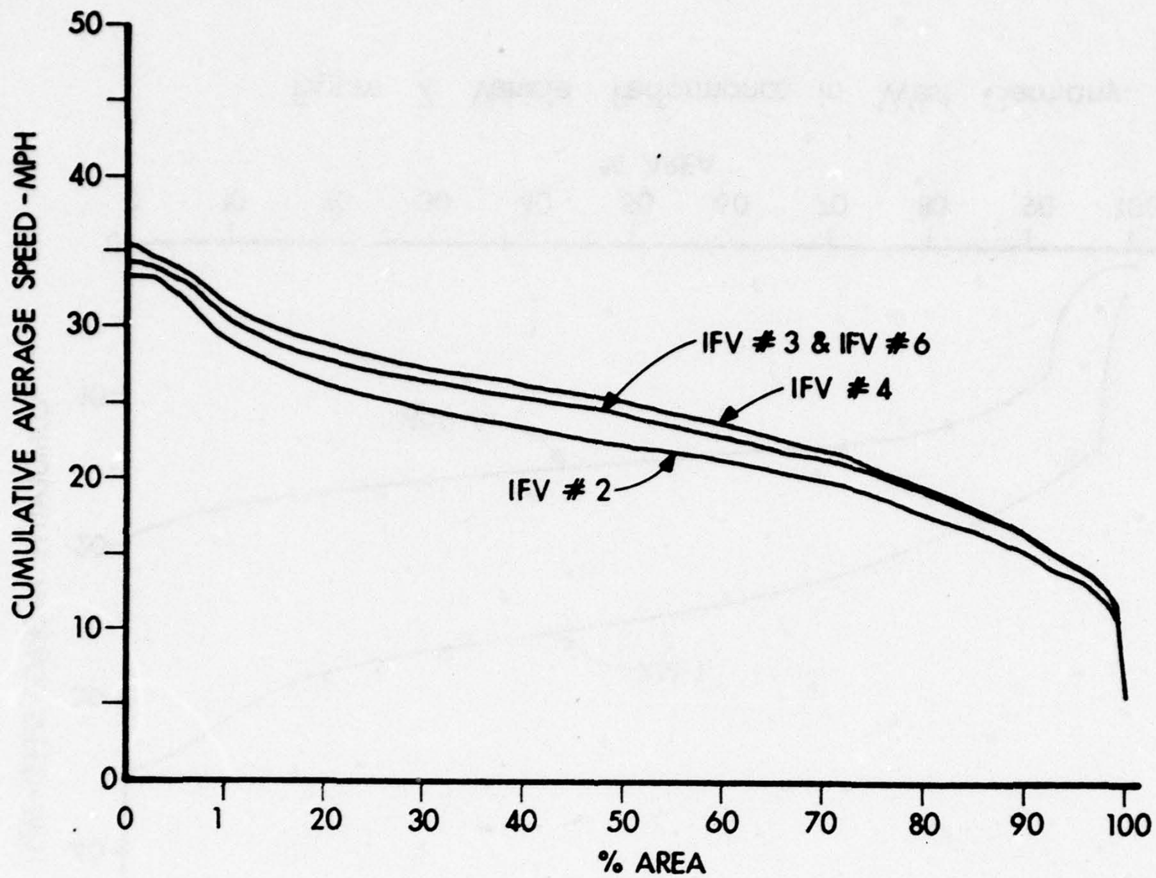

Figure 6. Vehicle Performance in West Germany.

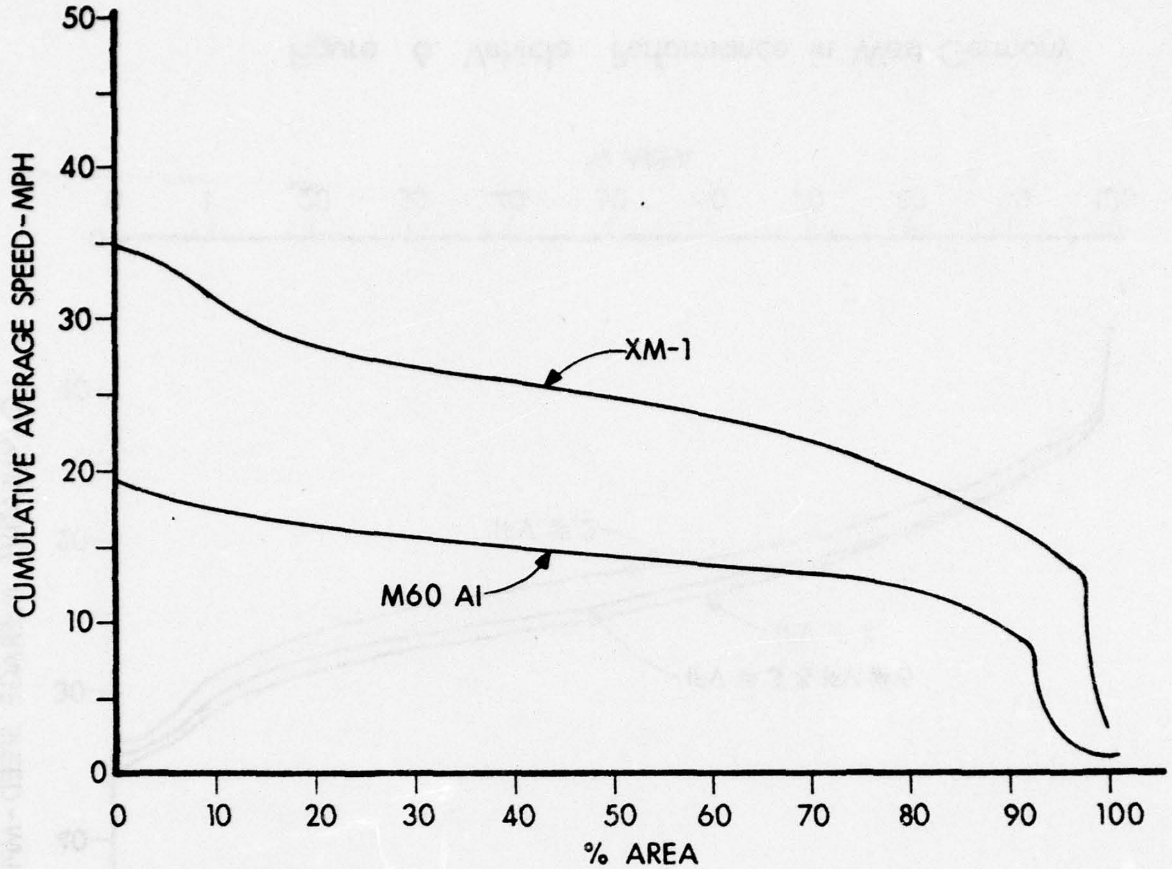

Figure 7. Vehicle Performance in West Germany.

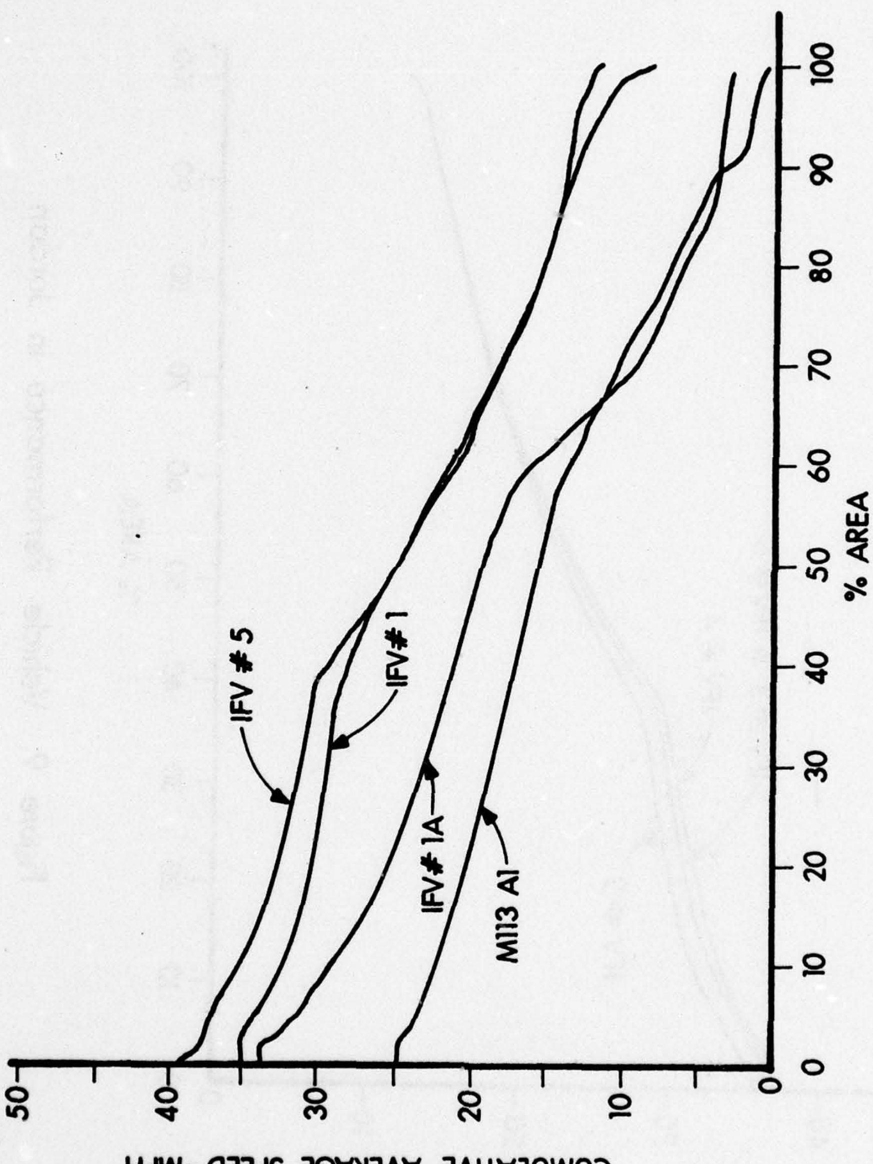

Figure 8. Vehicle Performance in Jordan

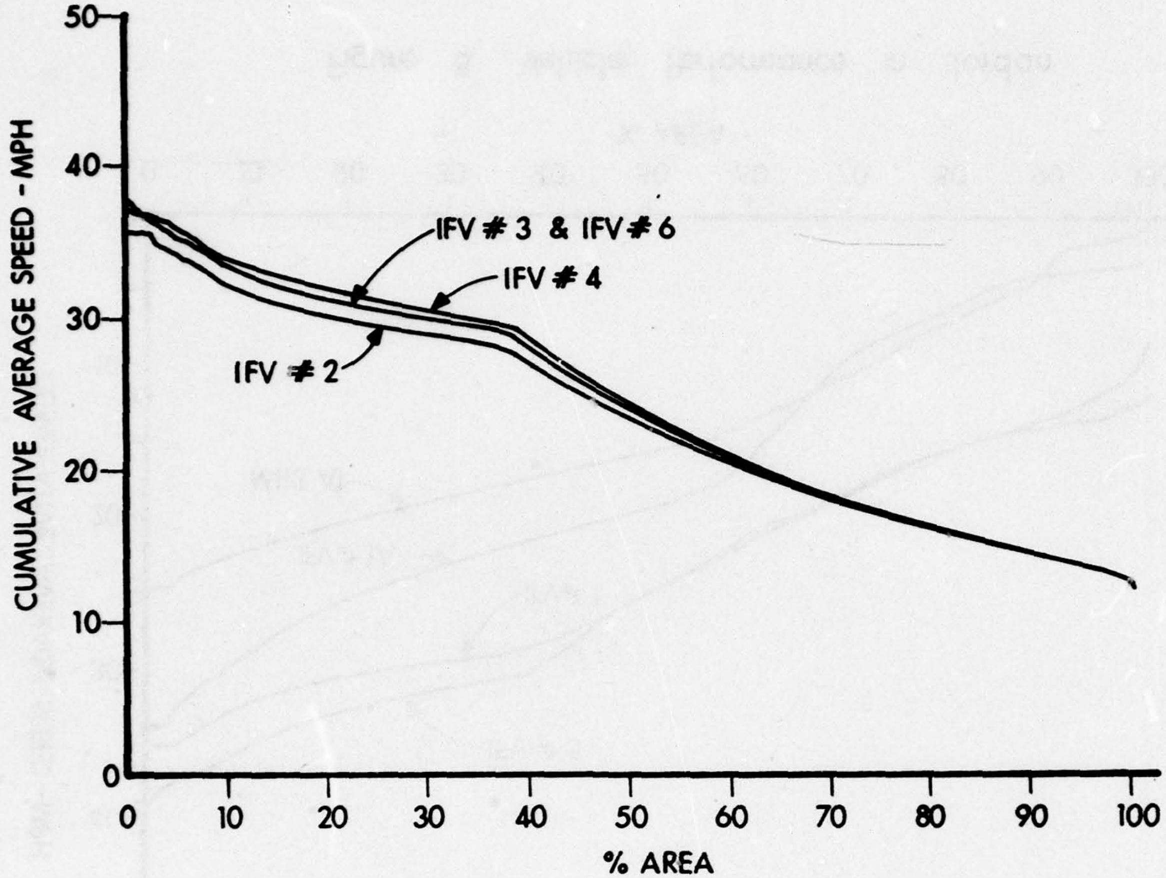

Figure 9. Vehicle Performance in Jordan.

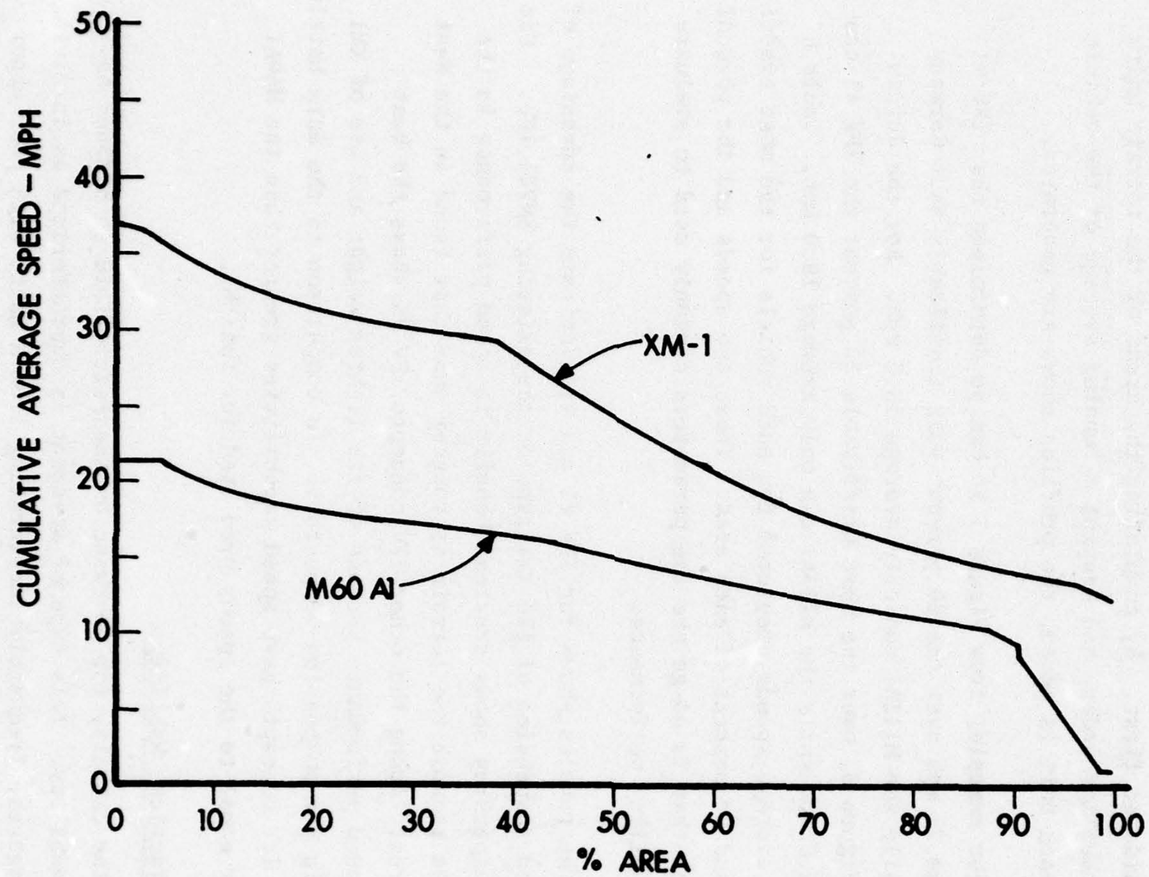

Figure 10. Vehicle Performance in Jordan.

10 for the two previously discussed terrain areas in Jordan and West Germany during wet season conditions. These profiles are generated by first ordering the terrain units in an area according to trafficability, with the terrain units in which the vehicle attains the greatest speed considered first. By cumulating the areas of the terrain units in trafficability order, and keeping a running average of the vehicle speed as each unit is added, the profiles shown are generated.

For example, from Figure 5 it can be determined that IFV #1 can average 25 mph over the 30 percent most trafficable West Germany terrain while the M113A1 can only average 18.0 mph. For the Jordan terrain, Figure 8, over the most trafficable 30 percent the IFV #1 can average 29.0 mph while the M113A1 can only average 19.0 mph. Table 8 lists the average speeds predicted for each vehicle for the most trafficable 50 and 90 percent of each area. These two speeds and the percent of the area that is no-go are the parameters commonly used to evaluate vehicle mobility performance.

The results shown for IFV #1 and #1A indicate the advantage of an improved suspension of the XM1 type on the existing XM723 IFV. Use of this suspension shows greatest benefit in speed performance in the Jordan area because the terrain is rougher than that found in the West Germany area. Among the other IFV concepts IFV #5 shows the best average speed performance because of its lighter weight and use of XM1 power train and suspension components. In comparison to the main battle tanks all IFV concepts have speed capabilities greater than the M60A1 and nearly equal to the speeds predicted for the XM1.

C. Tactical Mobility

The capacity for movement on the battlefield is defined as tactical mobility. This type of movement is characterized as involving short distances, frequently accelerating from a halt, with poor opportunity for selection of the most trafficable terrain.

Table 8 Predicted Vehicle Mobility: Cumulative Average Speeds

Vehicle	West Germany Area			Jordan Area		
	V_{50}, MPH	V_{90}, MPH**	Percent No Go*	V_{50}, MPH	V_{90}, MPH**	Percent No Go*
M113A1	17.0	10.5	5.2	15.6	3.1	9.9
IFV #1	22.5	16.3	.9	25.1	13.2	-
IFV #1A	21.3	14.8	1.7	19.3	3.7	-
IFV #2	22.4	15.1	.7	23.5	14.3	-
IFV #3 & #6	24.3	16.1	.7	24.1	14.4	-
IFV #4	25.2	16.5	.7	24.4	14.3	-
IFV #5	29.9	18.0	.7	25.0	13.8	-
M60A1	14.3	9.4	7.7	15.1	9.5	9.6
XM1	24.7	16.0	2.4	24.5	14.2	-

*Denotes percent of area.

**Where no-go areas are included, a speed capability of .1 mph is arbitrarily assumed for those terrain units.

The first measure of tactical mobility addressed is off-road acceleration. The significance of this capability on the battlefield is that it provides for crossing gaps between cover positions in minimum time and for recovering speed quickly after impediments are crossed. Consequently, the AMSAA acceleration model was employed to examine vehicle acceleration performance in combinations of the soil strength and slope conditions occurring in the West Germany area. Figures 11 through 16 show typical velocity versus distance results. Table 9 summarizes the acceleration performance predicted for a range of fine grain soil strength and slope conditions.

The soil strength condition of 130 RCI represents the firmest soil condition while the condition of 36 RCI represents the weakest soil strength conditions in the West Germany area. Figures 11 and 12 depict the predicted acceleration performance in the firmest soil and slope conditions of 0 and 15 percent for IFV concepts #2 and #5 which represent the heaviest and lightest weight IFV concept vehicles employing the XM1 power train. As shown in Table 8 , IFV #2, with a HP/TON ratio of 23.1, requires 7.8 seconds to reach 20 mph while IFV #5, with a HP/TON ratio of 45.7, requires 3.7 seconds to reach the same speed. In the weaker soil strength condition, shown in Figure 13 IFV #5 requires 4.3 seconds to reach 20 mph while IFV #2 reaches a maximum speed of only 14.3 mph. Figures 12 and 14 show similar predicted performance for both vehicles operating in these same soil strength conditions with a 15% slope.

Table 9 shows the predicted times and resulting speeds for each vehicle to accelerate from a standing start and travel distances of 100 or 200 meters. As expected the light weight, high HP/TON ratio IFV #5 is predicted to have the minimum times.

Another vehicle performance measure examined for tactical mobility was vehicle maximum speed performance on fine grain soil slopes. These results, shown in Table 10, also show the advantage of low vehicle gross weight and high values of engine horsepower. IFV #5 is predicted to have the best performance and in many conditions exceeds the performance of the XM1.

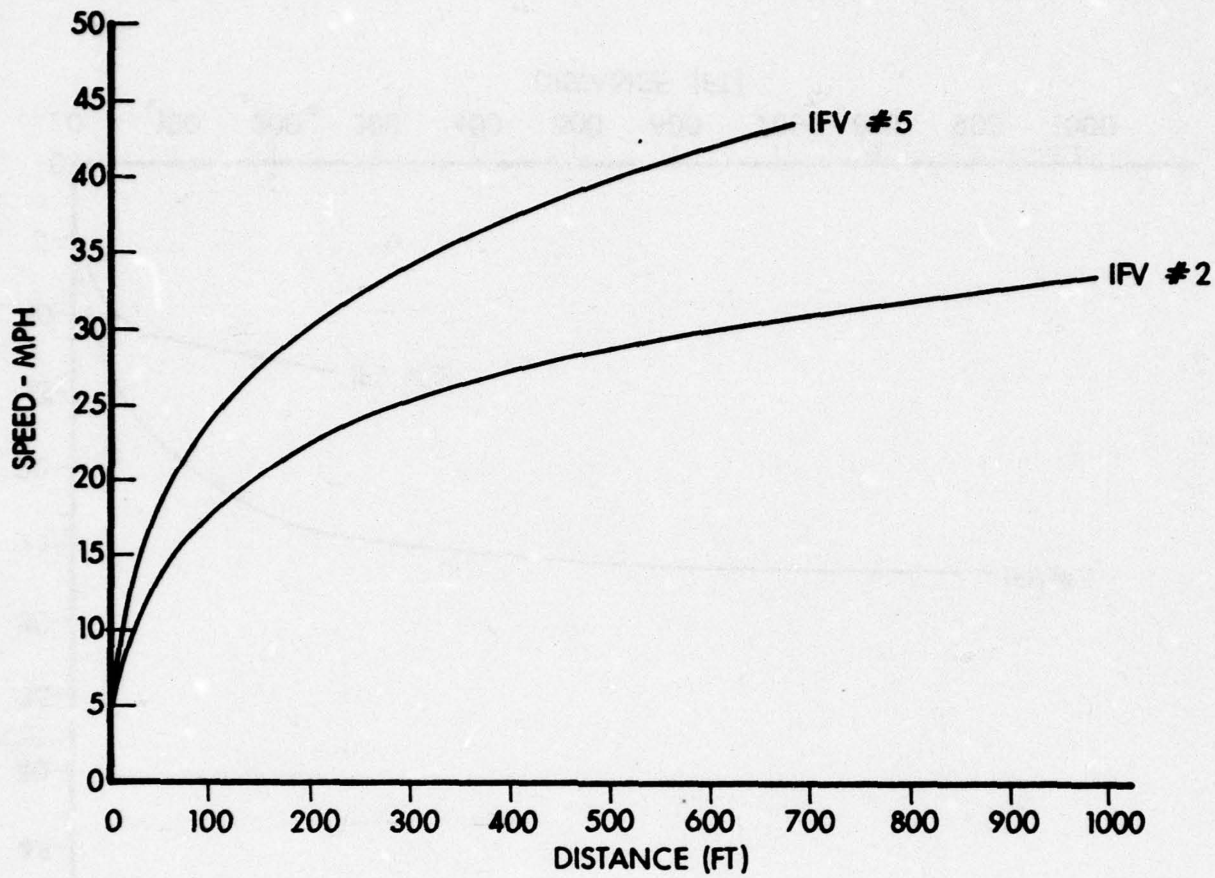

Figure 11. Acceleration on 130 RCI Fine Grain Soil and 0% Slope.

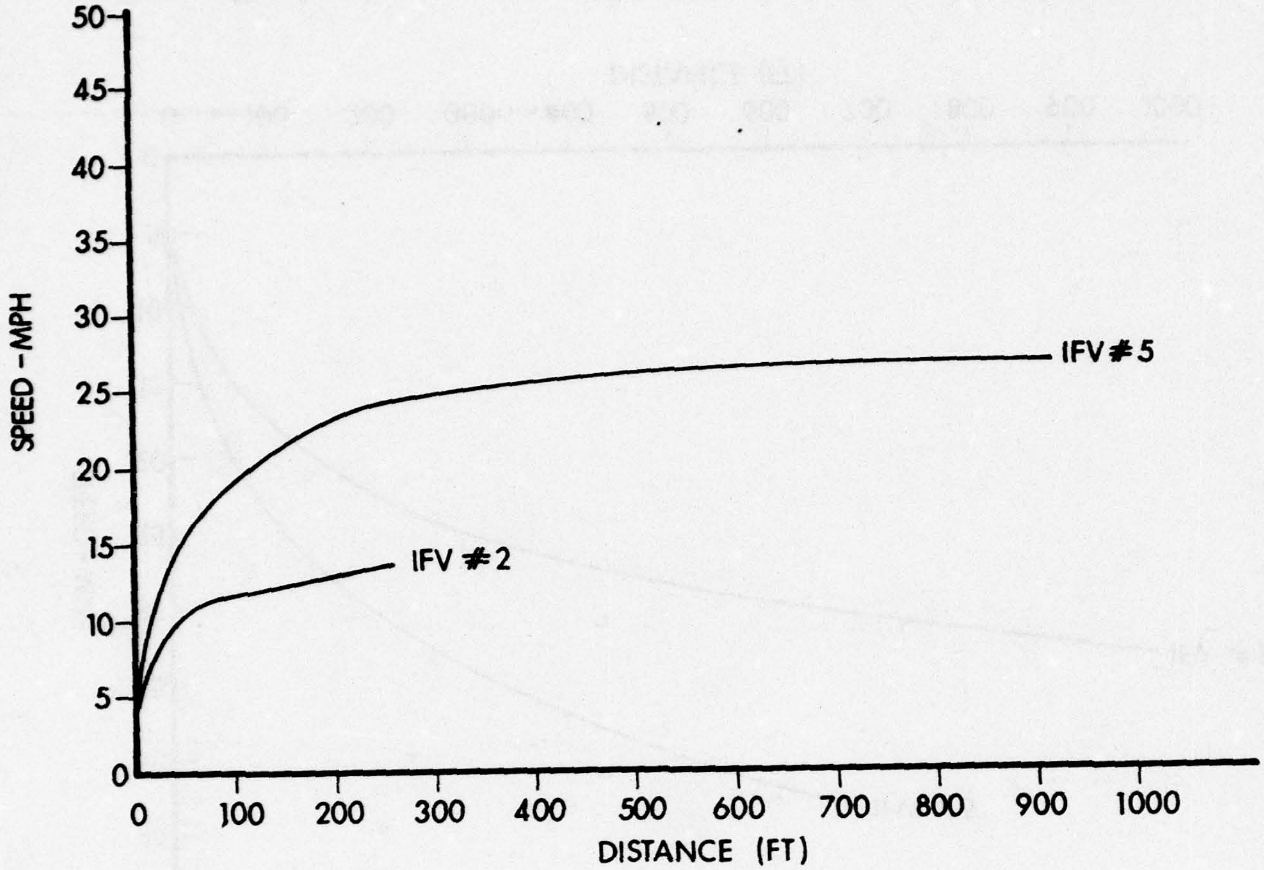

Figure 12. Acceleration on 130 RCI Fine Grain Soil and 15% Slope.

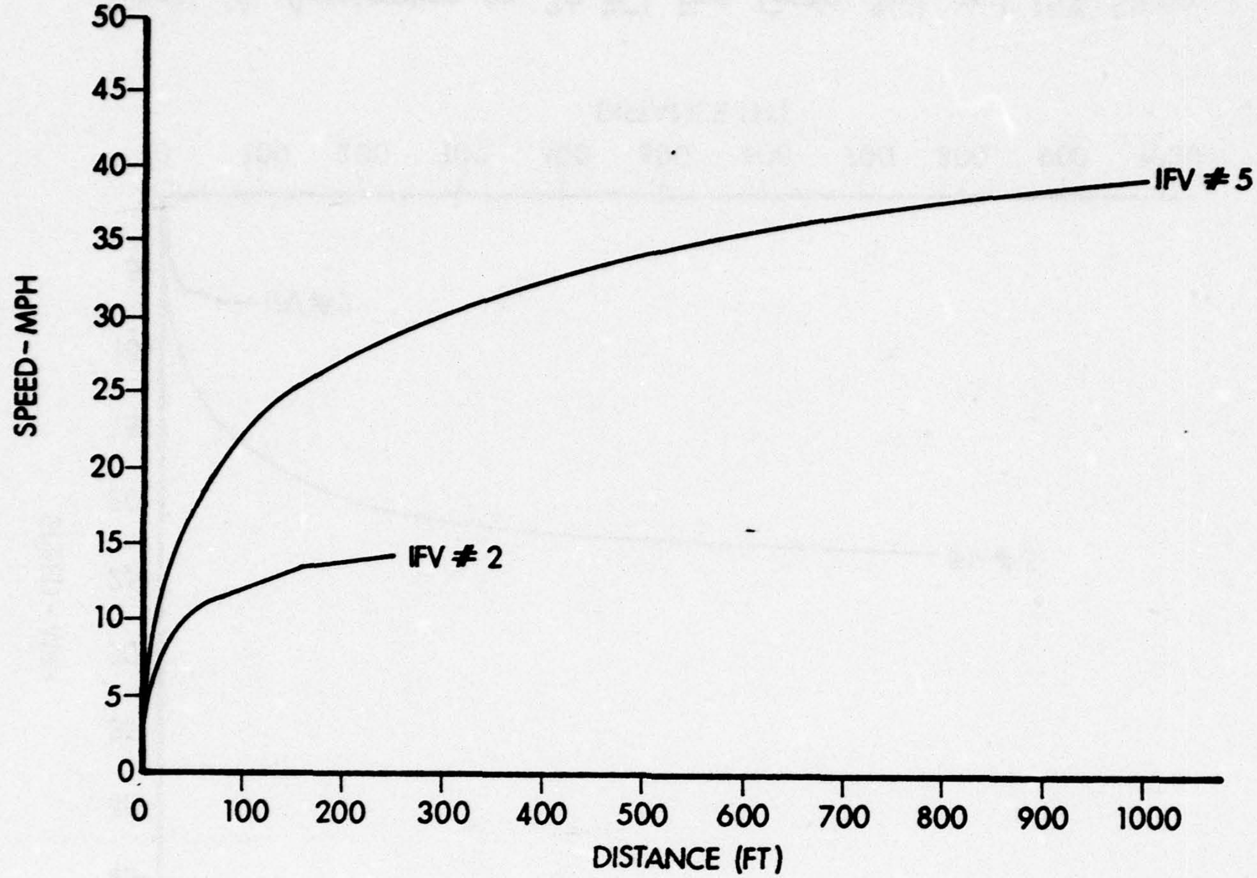

Figure 13. Acceleration on 36 RCI Fine Grain Soil and 0% Slope.

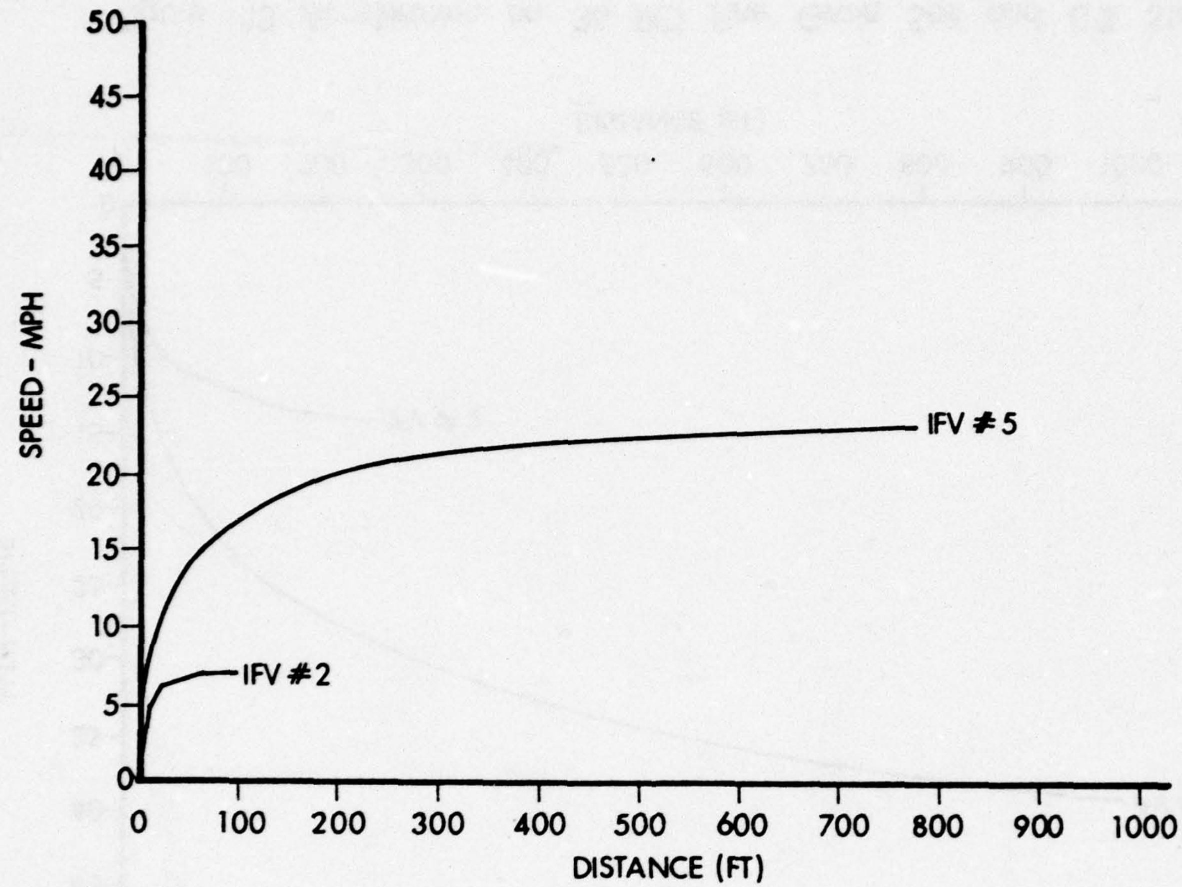

Figure 14. Acceleration on 36 RCI Fine Grain Soil and 15% Slope.

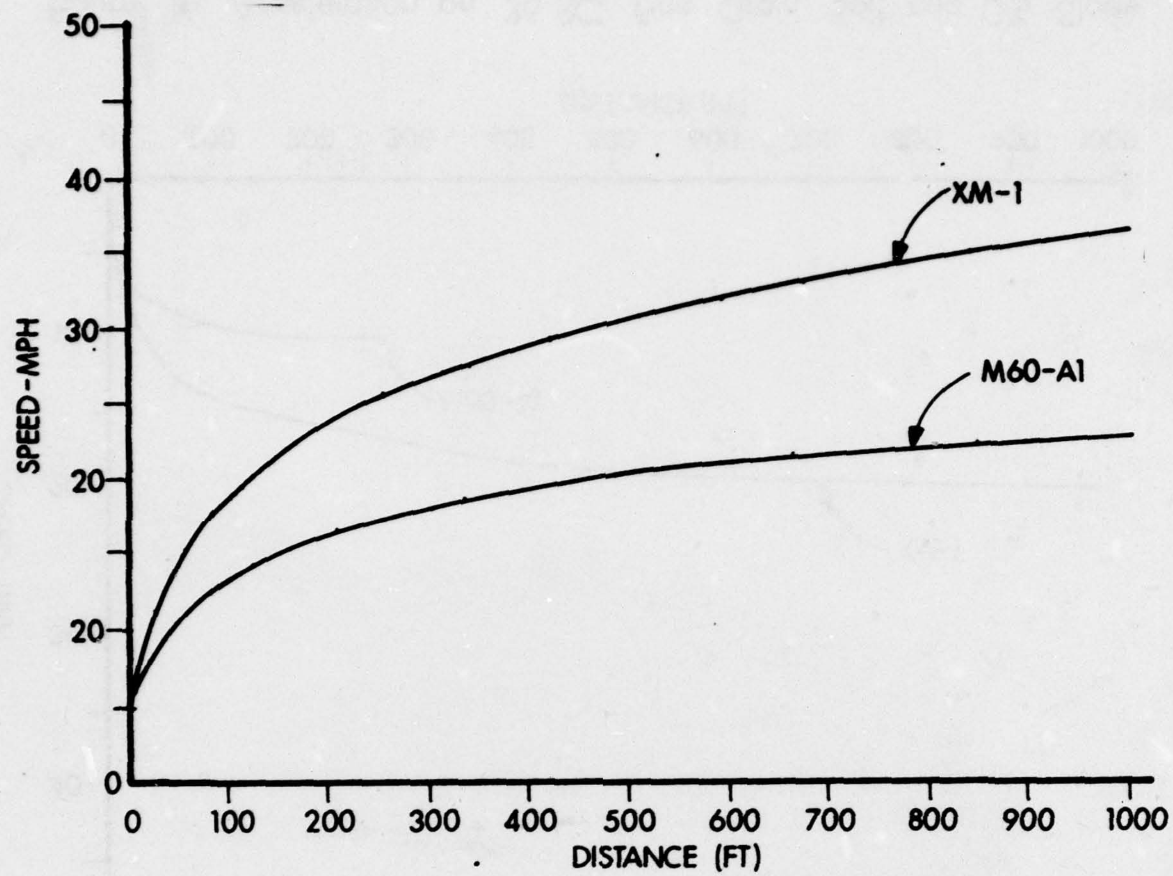

Figure 15. Acceleration on 130 RCI Fine Grain Soil and 0% Slope.

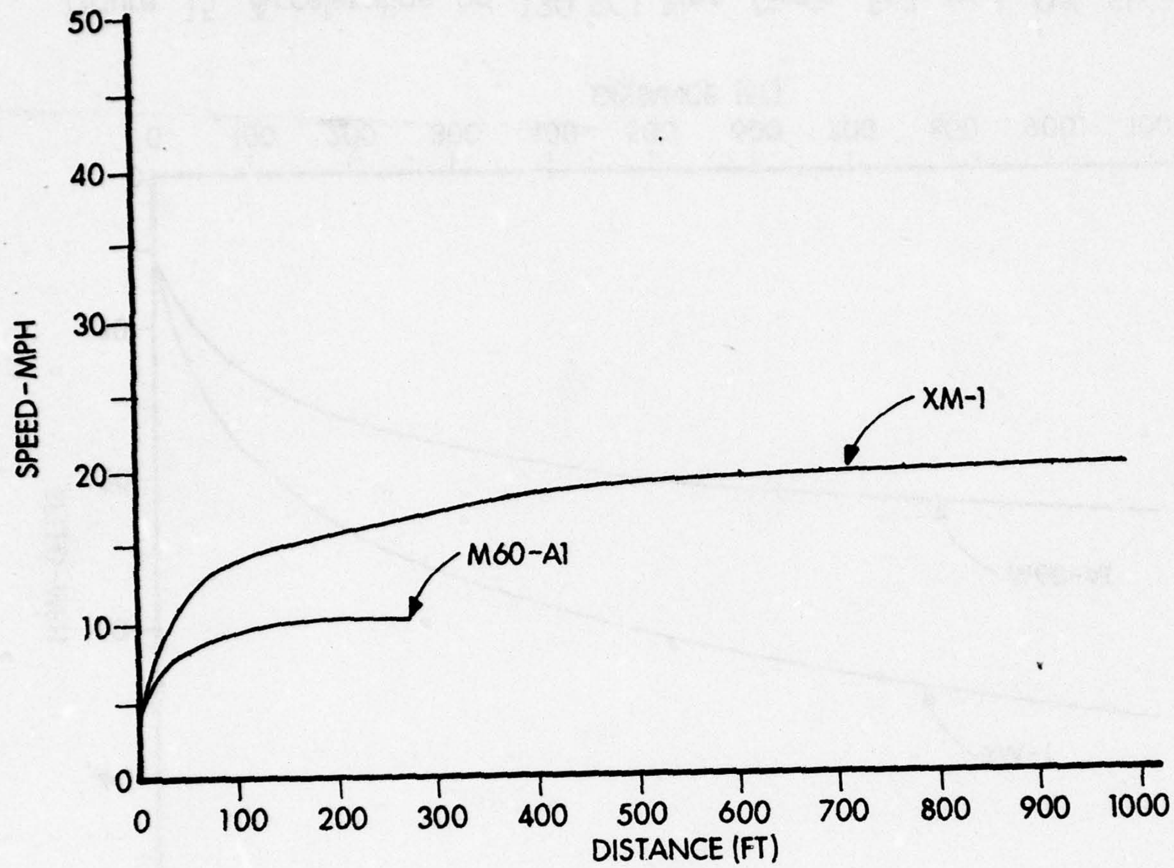

Figure 16. Acceleration on 36 RCI Fine Grain Soil and 0% Slope.

Table 9 Predicted Vehicle Acceleration Performance in Fine Grain Soil*

Vehicle	Soil Strength RCI	Slope %	Time to Reach "X" Speed, seconds 10 mph	20 mph	30 mph	Max. Speed Reached, mph	Time Required to Travel "X" Meters, sec. 100	200
M113A1	130	0	2.9	10.9	59.6	34.7	14.6	24.4
		10	5.1	-	-	11.3	22.2	42.0
		15	9.0	-	-	10.6	24.0	45.1
IFV #1 & #1A		0	2.3	8.2	24.4	38.5	13.4	21.6
		10	3.8	-	-	16.9	17.7	31.2
		15	6.5	-	-	12.4	21.5	39.6
IFV #2		0	2.5	7.8	19.7	42.7	13.2	21.0
		10	3.6	-	-	19.3	17.2	29.7
		15	4.8	-	-	14.1	19.8	35.6
IFV #3 & #6		0	2.4	7.0	16.5	43.7	12.7	20.1
		10	3.2	20.2	-	21.3	16.1	27.1
		15	4.0	-	-	14.6	18.6	33.9
IFV #4		0	2.3	6.4	14.7	43.7	12.3	19.5
		10	3.0	14.9	-	23.5	15.4	25.8
		15	3.6	-	-	15.5	17.8	32.0
IFV #5		0	1.6	3.7	7.3	43.7	10.0	15.6
		10	1.9	5.1	15.3	35.6	11.6	19.0
		15	2.1	6.3	-	26.8	12.5	21.1
M113A1	36	0	4.1	-	-	17.3	19.2	33.5
		10	-	-	-	9.9	25.7	48.3
		15	-	-	-	7.6	34.0	63.6
IFV #1 & #1A		0	3.1	17.7	-	22.1	15.7	26.4
		10	8.0	-	-	11.5	22.6	42.2
		15	-	-	-	7.7	27.7	52.6

Table 9 Predicted Vehicle Acceleration Performance in Fine Grain Soil* (Cont'd)

Vehicle	Soil Strength RCI	Slope %	Time to Reach "X" Speed, seconds 10 mph	20 mph	30 mph	Max. Speed Reached, mph	Time Required to Travel "X" Meters, sec. 100	200
IFV #2	36	0	4.8	-	-	14.3	19.4	35.0
		10	-	-	-	9.0	27.7	52.6
		15	-	-	-	7.1	34.1	65.7
IFV #3 & #6		0	2.4	-	-	19.1	17.3	29.6
		10	7.4	-	-	10.7	23.7	44.5
		15	-	-	-	9.0	27.7	52.6
IFV #4		0	3.4	29.5	-	20.2	16.5	28.0
		10	6.0	-	-	11.3	22.7	42.5
		15	-	-	-	9.6	26.0	49.3
IFV #5		0	1.6	4.3	10.0	43.4	10.8	17.4
		10	2.0	6.5	-	25.8	12.6	21.4
		15	2.3	9.5	-	23.4	13.9	23.7
XM-1	130	0	2.3	6.7	15.8	43.7	12.5	19.9
		10	3.1	17.7	-	21.9	15.8	26.6
		15	3.9	-	-	14.9	18.3	33.3
M60A1		0	4.0	21.0	-	23.7	16.9	27.8
		10	14.7	-	-	10.2	24.8	46.8
		15	-	-	-	7.7	30.9	59.8
XM-1	36	0	3.5	20.0	-	20.2	16.7	28.2
		10	6.3	-	-	11.1	22.9	43.0
		15	-	-	-	9.4	26.5	50.2
M60A1		0	11.0	-	-	10.6	24.2	45.4
		10	-	-	-	6.5	36.0	70.3
		15	-	-	-	5.2	44.8	88.1

*Based on vehicle standing start.

Table 10 Predicted Vehicle Speeds on Fine Grain Soil Slopes

	Soil Strength								
	60 RCI Slope			120 RCI Slope			290 RCI Slope		
Vehicle	0%	20%	40%	0%	20%	40%	0%	20%	40%
M113A1	21.2 mph	6.2 mph	2.3 mph	35.8 mph	8.5 mph	2.5 mph	41.8 mph	9.1 mph	2.6 mph
IFV #1 & 1A	25.7	7.2	3.6	43.8	7.5	4.4	46.8	7.6	4.8
IFV #2	27.7	9.0	5.4	42.2	10.5	5.8	43.8	11.0	6.0
IFV #3 & #6	31.7	10.2	5.9	43.7	11.4	6.2	43.8	13.8	6.3
IFV #4	34.3	10.9	6.1	43.7	13.9	6.4	43.8	14.2	6.5
IFV #5	43.6	22.0	10.9	43.8	23.7	13.3	43.9	24.1	13.5
M60A1	16.3	5.5	2.0	23.4	6.3	2.4	30.0	6.7	2.6
XM1	33.0	10.5	6.0	43.7	11.6	6.3	43.8	13.9	6.4

The final and most comprehensive performance measure examined to evaluate tactical mobility is actual cross-country speed capability as a function of terrain trafficability. This was done by using the mobility profiles developed by the Army Mobility Model. However, in keeping with our consideration of tactical movements the speed shown in Figures 17 through 22, are actual speeds which indicate how fast the vehicle can go in a specific percentile terrain, rather than the average speed over all the terrain up to that point. Table 11 shows the actual speeds for the 50 and 90 percentile terrains and the total percentage of each area that is no-go. Table 12 provides breakdown of factors causing vehicle no-go's. Table 13 provides a breakdown of the factors limiting vehicle speeds as considered in the Army Mobility Model.

As shown in Table 11, all the IFV concepts have actual speed capabilities significantly greater than both the M113A1 and M60A1 MBT. Among the IFV concepts employing the XM1 powertrain and suspension (IFV) #2 through IFV #6) IFV #5 shows slightly faster speeds in the West Germany terrain and all concepts show equal predicted actual speed performance in the Jordan terrain. In comparison to the XM1, only the IFV concept #5 is predicted to have a speed advantage and this only occurs in the West Germany terrain.

For no-go conditions in the West Germany Terrain, shown in Table 12, available traction is the predominate factor in causing no-go's for the IFV concepts employing XM1 components. All other vehicles have no-go's due to obstacles and in some cases also available traction.

Predicted performance for the Jordan terrain indicates equal performance for all IFV concepts except IFV #1 (XM723 with XM1 suspension). This 1 to 2 mph speed advantage probably reflects the slightly better braking capability of IFV #1 which is used to its advantage in the obstacle spacings found in the Jordan terrain. Only the M113A1 and M60A1 have no-go areas and these are caused by obstacles.

Comparison of the predictions made for IFV #1 and IFV #1A in both terrain areas indicate that use of an XM1 type suspension yields approximately a 2 mph actual speed improvement for the fifty percentile terrain. It also reduces the percent no-go's caused in West Germany

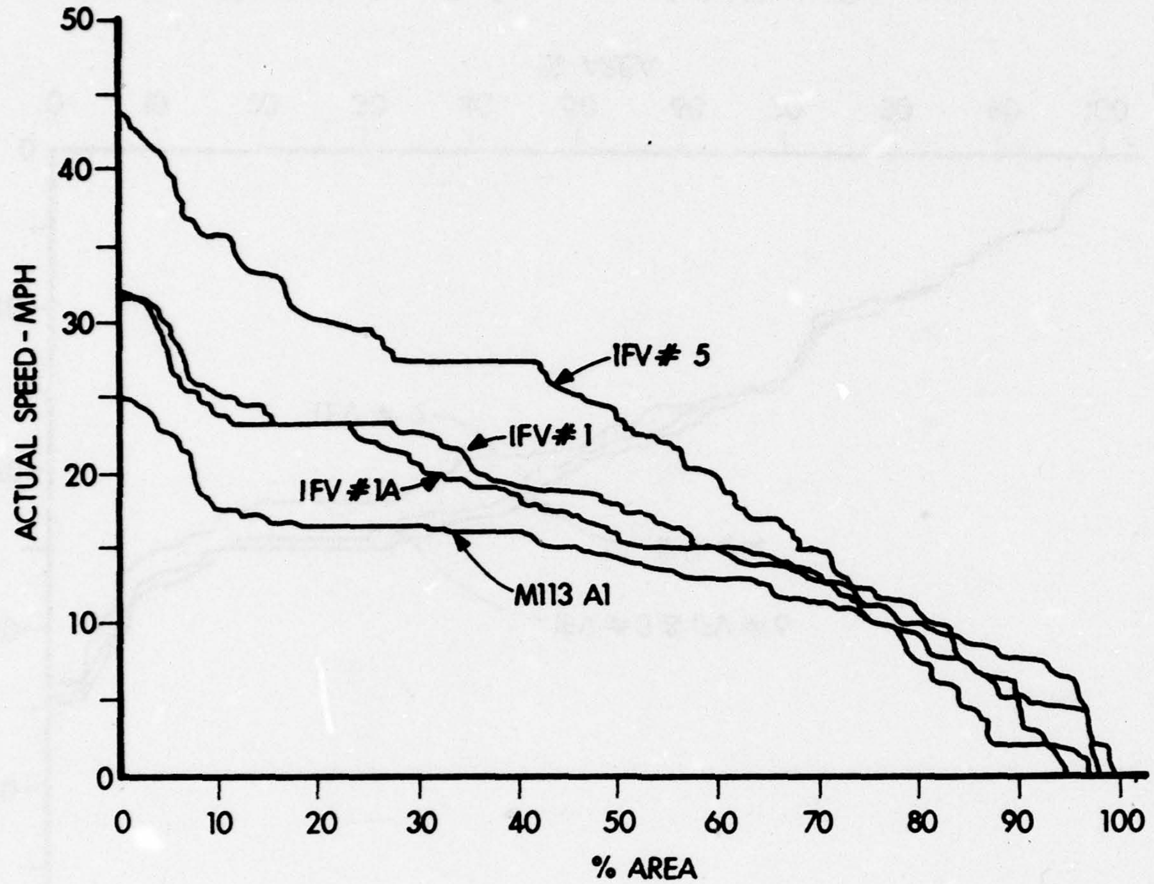

Figure 17. Vehicle Performance in West Germany.

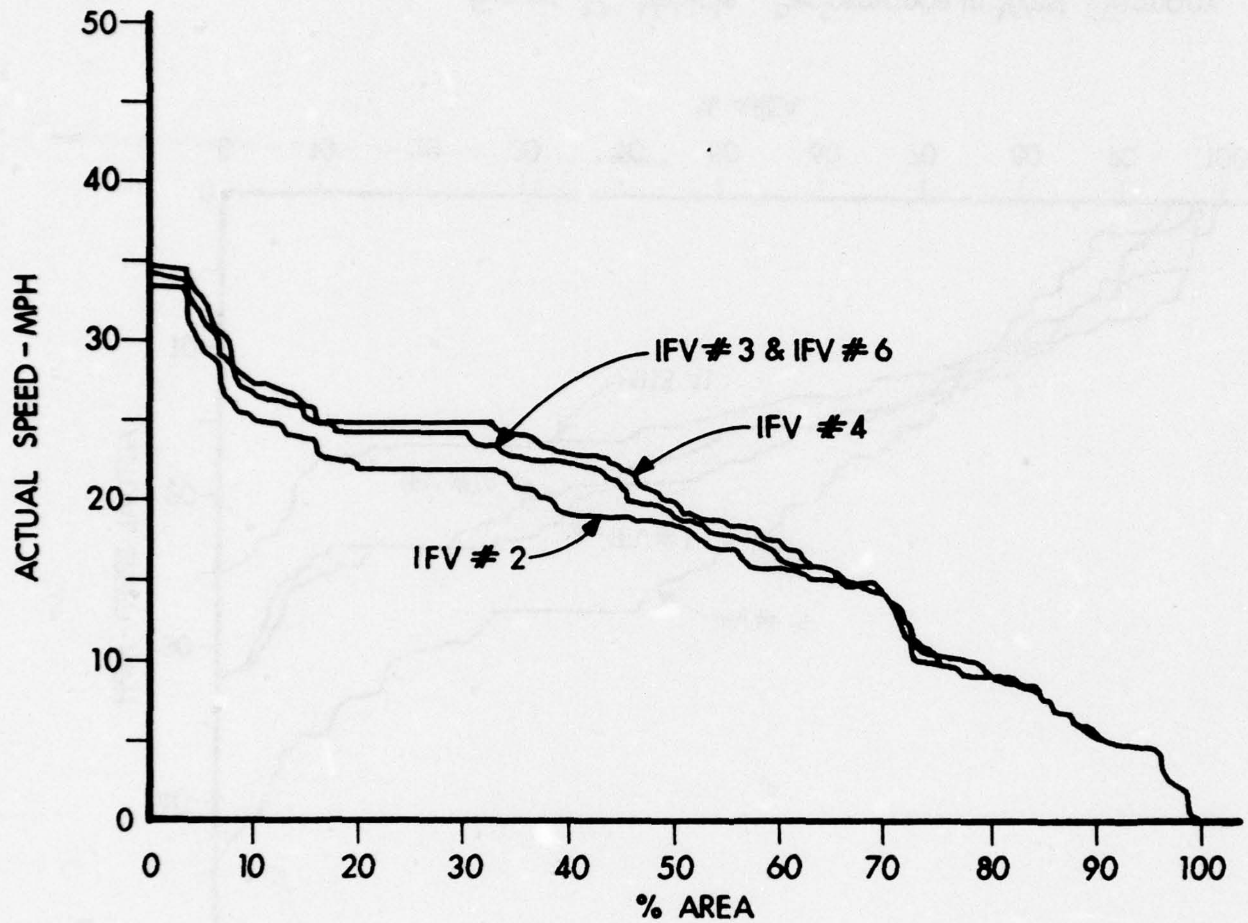

Figure 18. Vehicle Performance in West Germany.

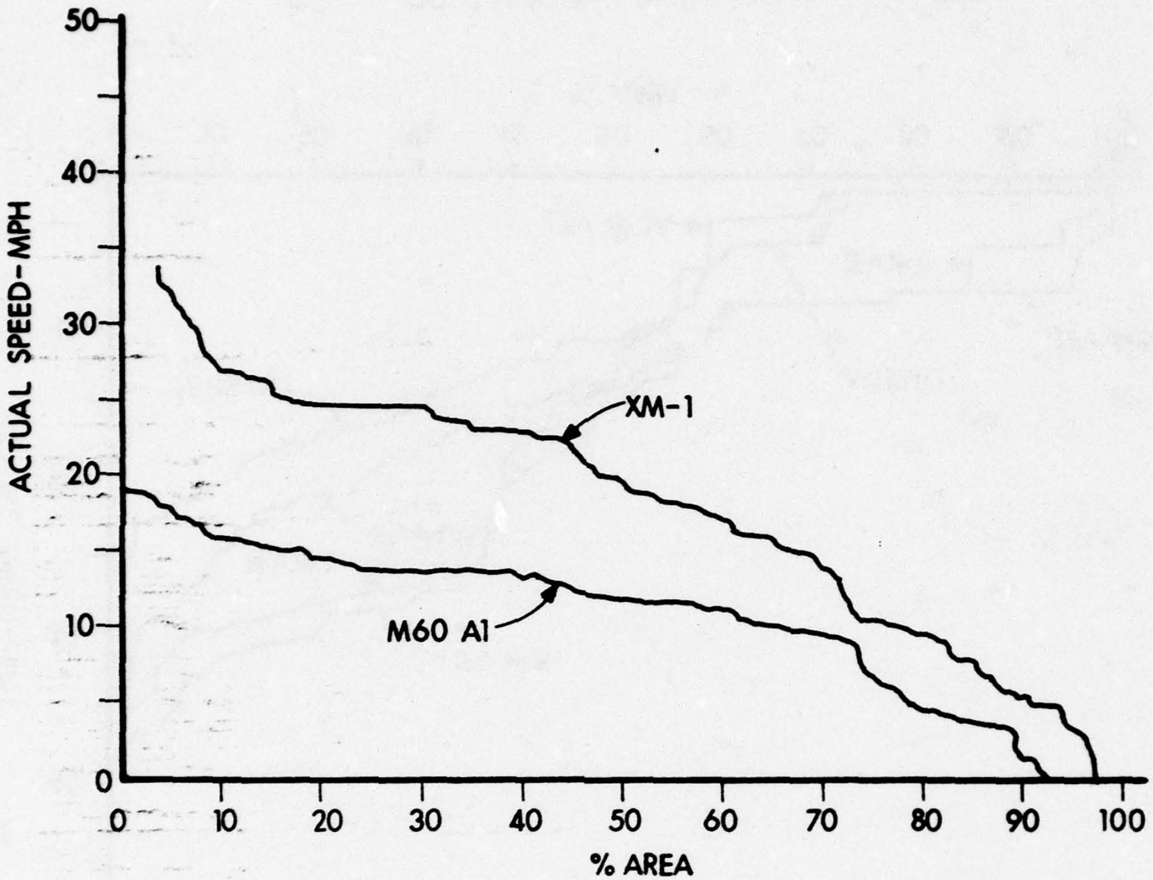

Figure 19. Vehicle Performance in West Germany,

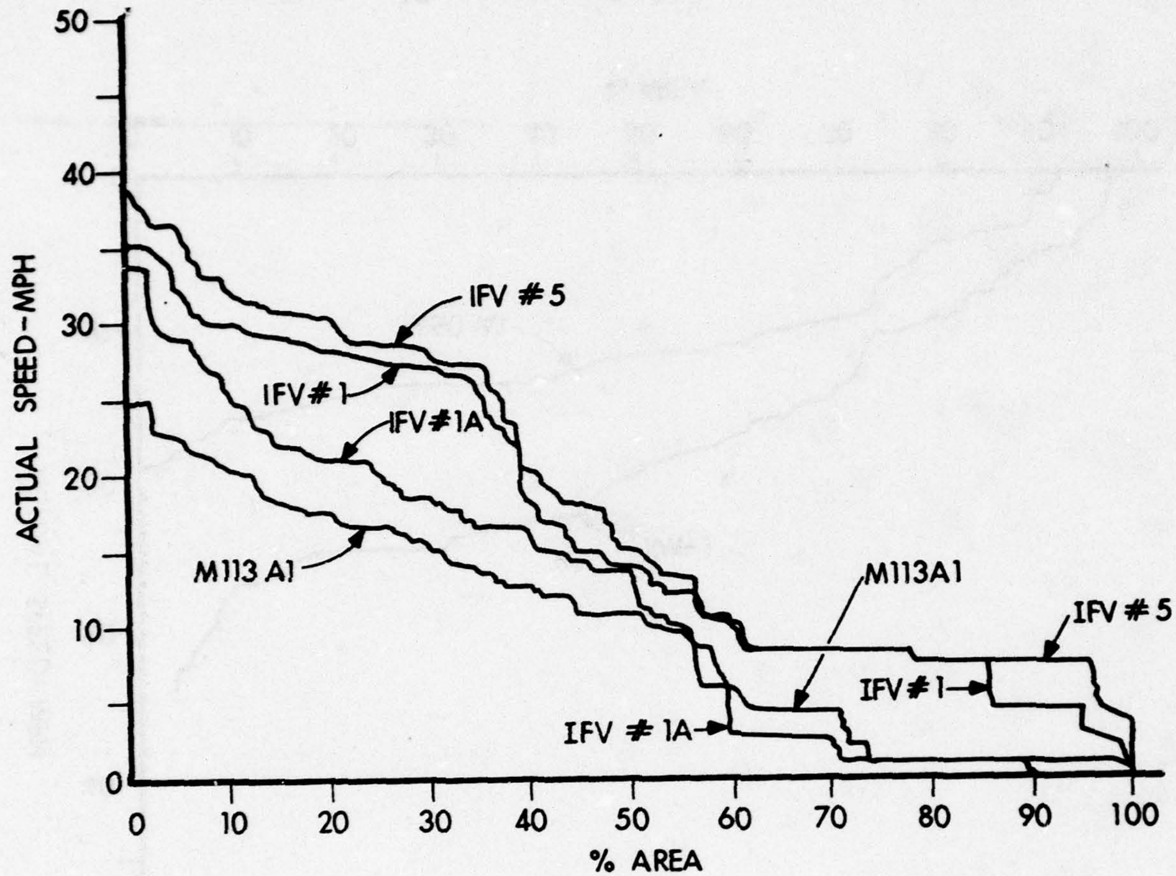

Figure 20. Vehicle Performance in Jordan.

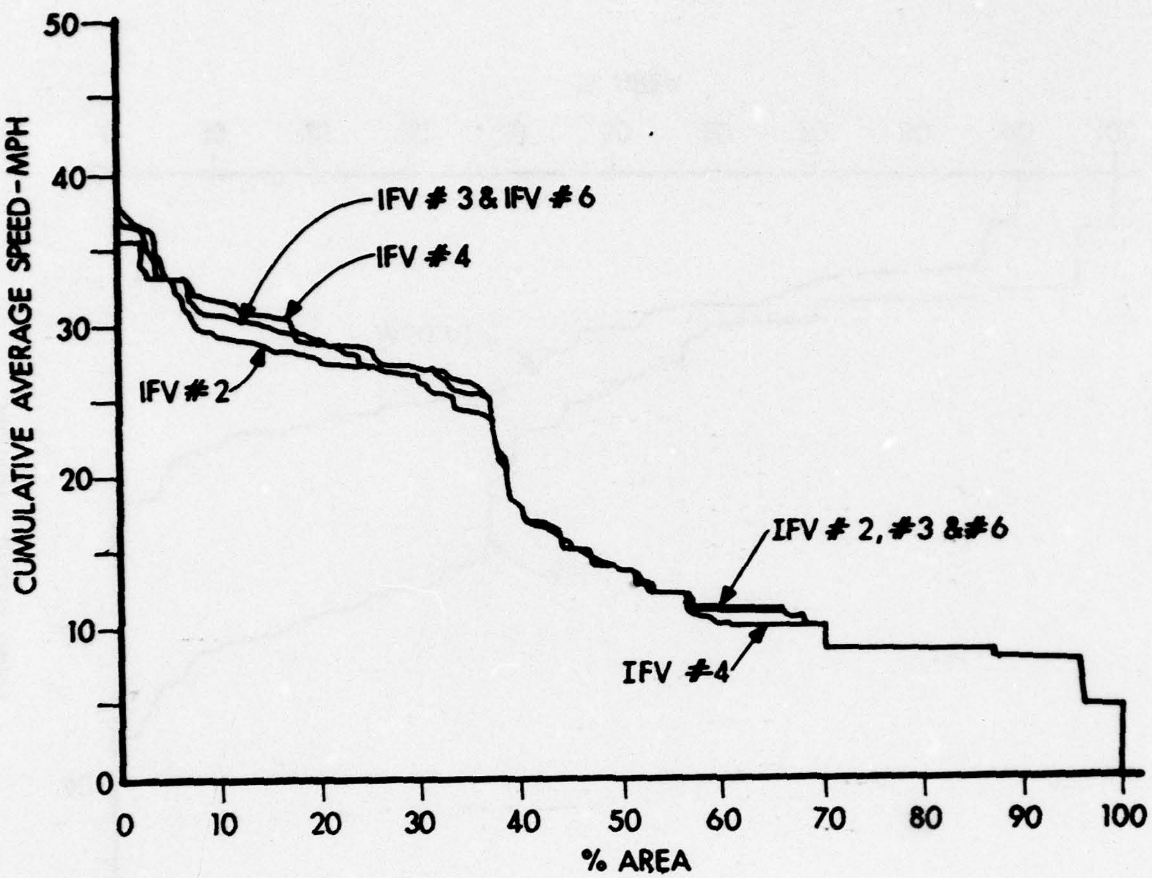

Figure 21. Vehicle Performance in Jordan.

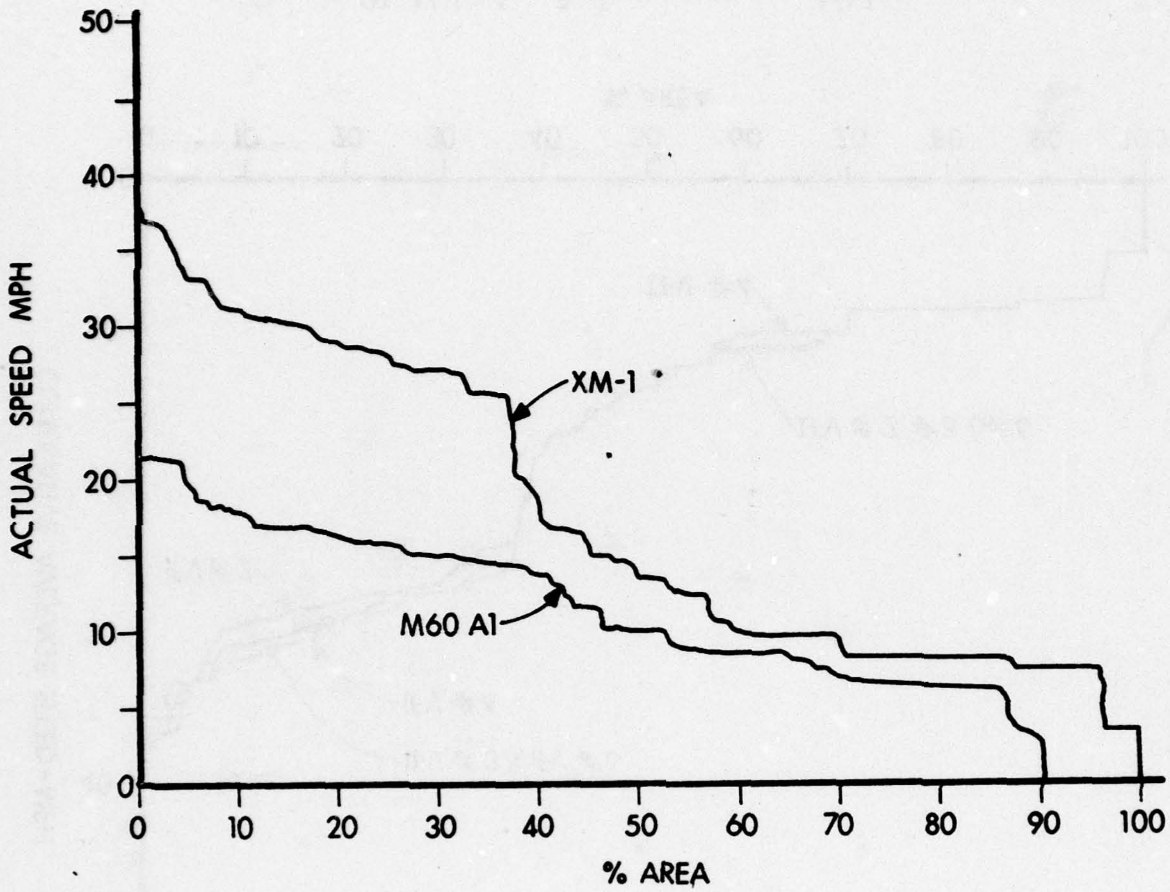

Figure 22. Vehicle Performance in Jordan.

Table 11 Predicted Vehicle Mobility: Actual Speeds

	West Germany Area			Jordan Area		
Vehicle	V_{50}, MPH	V_{90}, MPH	Percent No Go*	V_{50}, MPH	V_{90}, MPH	Percent No Go*
M113A1	14.4	2.0	5.2	10.8	0.1	9.9
IFV #1	18.0	7.7	.9	15.0	4.6	-
IFV #1A	16.1	4.8	1.7	13.3	1.1	-
IFV #2	18.5	5.1	.7	13.9	7.6	-
IFV #3 & #6	19.1	5.3	.7	13.9	7.6	-
IFV #4	20.0	5.5	.7	13.9	7.7	-
IFV #5	23.4	5.5	.7	13.9	7.6	-
M60A1	11.8	1.5	7.7	10.0	3.0	9.6
XM1	19.6	5.4	2.4	13.5	7.6	-

*Denotes percent of area.

Table 12 Areal Occurrence of Vehicle No-Go's

Vehicle	Area	Surface Strength Less Than VCI	Avail. Traction Less Than Soil & Slope Resistance	Obstacle Performance	Avail. Traction Less Than Total Resistance Forces
		Factors Causing Vehicle No Go's			
M113A1	WEST GERMANY	-	.1	5.1	-
IFV #1	WEST GERMANY	-	-	.9	-
IFV #1A	WEST GERMANY	-	-	1.7	-
IFV #2	WEST GERMANY	-	-	-	.7
IFV #3&#6	WEST GERMANY	-	-	-	.7
IFV #4	WEST GERMANY	-	-	-	.7
IFV #5	WEST GERMANY	-	-	-	.7
M60A1	WEST GERMANY	-	-	5.3	2.4
XM1	WEST GERMANY	-	-	1.7	.7
M113A1	JORDAN	-	-	9.9	-
IFV #1	JORDAN	-	-	-	-
IFV #1A	JORDAN	-	-	-	-
IFV #2	JORDAN	-	-	-	-
IFV #3&#6	JORDAN	-	-	-	-
IFV #4	JORDAN				
IFV #5	JORDAN	-	-	-	-
M60A1	JORDAN	-	-	9.6	-
XM1	JORDAN	-	-	-	-

Table 13 Areal Occurrence of Factors Limiting Vehicle Speeds

Vehicle	Area	Ride	Soil & Slope Resist.	Visibility	Maneuvering	All Resist. Forces	Accel. & Decel. Between Obstacles	Urban Areas
		Factors Limiting Vehicle Speeds						
M113A1	West Germany	1.8	49.1	-	18.4	18.7	1.7	All vehicles have speeds limited by urban areas in 4.5% total area.
IFV #1		.2	47.0	2.1	18.7	23.3	2.9	
IFV #1A		1.4	45.6	2.0	15.7	20.9	7.7	
IFV #2		.8	37.6	4.2	18.1	29.8	3.8	
IFV #3 & #6		.8	51.6	6.4	18.2	11.9	5.6	
IFV #4		1.1	50.8	8.0	18.1	10.8	5.6	
IFV #5		2.8	27.0	37.4	18.2	2.0	7.0	
M60A1		.8	55.9	-	17.6	12.4	.6	
XM1		1.1	51.0	7.0	18.2	11.5	3.9	
M113A1	Jordan	18.9	8.7	-	12.1	3.3	44.6	All vehicles have speeds limited by urban areas in 2.2% of total area.
IFV #1		1.5	11.9	.9	24.9	20.1	38.1	
IFV #1A		22.2	4.0	.7	22.4	5.5	42.5	
IFV #2		.5	15.4	5.1	15.3	11.1	50.0	
IFV #3 & #6		3.0	9.7	10.3	14.7	8.1	51.5	
IFV #4		3.4	5.5	15.7	14.6	6.6	51.6	
IFV #5		4.0	-	27.1	15.3	-	51.1	
M60A1		4.2	13.2	-	13.7	16.5	40.2	
XM1		3.1	7.1	12.4	14.6	8.4	51.7	

terrain and increases the ninety percentile speeds for both areas because the XM1 type suspension allows impact with obstacles at higher speeds than those allowed with the current XM723 (IFV #1A) suspension.

V. CONCLUSIONS

In conclusion, of the new IFV concepts (IFV #2 through #6) evaluated all have predicted mobility performance equivalent to that predicted for the XM1. Because of its low weight and high horsepower IFV #5 has the best performance of all the IFV concepts. In the West Germany terrain the predominant factor controlling speed, see Table 13, is the traction available to overcome the resisting forces caused by soil and slope. In Jordan the predominant factor controlling vehicle speed is its acceleration and braking performance as controlled by the spacing of obstacles found in the area.

In comparison to the M113A1 and M60A1, all IFV concepts, including the existing XM723 (IFV #1A), offer superior mobility. From an armor/infantry team standpoint, the IFV concepts all appear compatible with the XM1 in overall mobility. However, in rough terrain conditions, the poorer ride characteristics of IFV #1A may have an adverse effect on the infantry squad if this vehicle attempts to match the pace of the XM1. Use of the M113A1 with the XM1 or any concept IFV with the M60A1 would seem to indicate the need for different tactics and command/control procedures if the full potential of the faster vehicles is to be realized.

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APPENDIX A: Army Mobility Model Input Data

The following listing contains the vehicle characteristic data used to define the IFV concepts considered in this evaluation. These data were developed from drawings provided by TARADCOM and from XM1 and MICV, XM723 data developed by AMSAA for previous evaluation efforts. The vehicle gross weight values associated with each concept were provided by the IFV TASK FORCE. In applying the XM1 power train characteristics to the IFV concepts no attempt was made to re-gear the vehicle to obtain a vehicle top speed similar to the existing XM723 IFV.

Listing of Vehicle Characteristics Data for IFV Concepts

	Characteristic	M113A1	IFV #1 & #1A	IFV #2	IFV#3 & #6	IFV #4	IFV #5
1.	Vehicle Model	M113A1	IFV 1	IFV 2	IFV 3/IFV 6	IFV 4	IFV 5
2.	Vehicle type 0 = tracked, 1 = wheeled	0	0	0	0	0	0
3.	Gross weight, lbs	24,000	47,000	130,000	118,000	110,000	65,600
4.	Track type, 0 = nonflexible, 1 = flexible	1	1	1	1	1	1
5.	Grouser height, inches	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5
6.	Gross rated HP	215	500	1500	1500	1500	1500
7.	No. of tracks	2	2	2	2	2	2
8.	Vehicle width, inches	105	127-3/4	143-3/4	143-3/4	143-3/4	143-3/4
9.	Vehicle length, inches	192	248	299	299	287	299
10.	Track width, inches	15	21	25	25	25	25
11.	Area of one track shoe, inches^2	90	126	193-3/4	193-3/4	193-3/4	193-3/4
12.	No. of road wheels	10	12	14	14	12	14
13.	Max. vertical step capability, inches	24	36	49	49	49	49
14.	Min. ground clearance, inches	16	17-1/4	19	19	19	19
15.	Rear end clearance, inches	24	31	49-1/4	49-1/4	49-1/4	49-1/4
16.	Departure angle, degrees	40	77-1/2	90	90	90	90
17.	Approach angle, degrees	70	90	65	65	65	65
18.	Length of track in contact with ground, inches	108	151	183	183	168	183
19.	Height of leading edge, inches	34	42	59.2	59.2	56.4	59.2
20.	Distance between 1st & last road wheel center lines, inches	105	148	180	180	165	180
21.	Horizontal distance from C.G. to 1st road wheel center line, inches	52.25	70-3/4	83.2	79.9	74.8	83.2
22.	Vertical distance from C.G. to Horizontal CL of road wheels, inches	24.25	27-3/8	32.9	31.0	28.6	32.9
23.	Track thickness + radius of rear sprocket or idler, inches	10.5	12.2	16.6	16.6	16.6	16.6
24.	Horizontal distance from C.G. to rear sprocket or idler, inches	77.25	105.5	132.8	136.2	130.0	132.8
25.	Vertical distance from horizontal center line of rear sprocket or idler to ground, inches	20	28.75	34.3	34.3	34.0	34.3
26.	Track thickness + road wheel radius, inches	14.75	14.75	15.63	15.63	15.63	15.63
27.	Sprocket pitch radius, inches	9.8	10.5	12.6	12.6	12.6	12.6

Listing of Vehicle Characteristics Data for IFV Concepts

	Characteristic	M113A1	IFV #1 & #1A	IFV #2	IFV#3 & #6	IFV #4	IFV #5
28.	Height of point used to determine approach angle, inches	26	42	59.2	59.2	56.4	59.2
29.	Maximum braking force/gvw	.56	.45	.39	.39	.39	.39
30.	Maximum vehicle speed, mph	42	47	44	44	44	44
31.	Distance vehicle spans before significant motion begins, inches	52-1/4	70-3/4	83.2	79.9	74.8	83.2
32.	Vehicle HP/Ton	17.9	21.3	23.1	25.4	27.3	45.7
33.	Max. force leading edge can withstand, kips	48	98	260	236	220	131
34.	Transmission type, 0 = automatic, 1 = manual	0	0	0	0	0	0
35.	Final drive ratio/eff., %	3.93/95	4.40/95	4.30/98	4.30/98	4.30/98	4.30/98
36.	No. gears in transmission	3	Infinitely variable	4	4	4	4
37.	Gear ratios (FWD)	3.81, 1.936	-	5.88, 3.04, 1.90, 1.28	5.88, 3.04, 1.90, 1.28	5.88, 3.04, 1.90, 1.28	5.88, 3.04, 1.90, 1.28
38.	Engine to torque converter gear ratio	N/R					
39.	Torque converter lockup, 0 = no, 1=Yes	N/R					
40.	Max. tractive force vs. speed array,	See separate listings					
41.	Ride limited speed vs roughness array	See separate listings					
42.	Obstacle impact speed vs obstacle height, mph vs inches	See separate listings					
43.	Angle between a line parallel to the ground & line connecting C.G. & center of rear sprocket or idler, degrees	13.8	7.2	6.1	5.5	4.5	6.1
44.	Distance from C.G. to the pivot point on track, inches	90.05	118.5	150.2	153.4	147.0	150.2

Vehicle Maximum Tractive Force vs. Speed, Data Item #40

M113A1		IFV #1 & #1A		IFV #2, #3, #4, #5, & #6	
Speed, mph	Force, lbs	Speed, mph	Force, lbs	Speed, mph	Force, lbs
0	17,950	0	46,500	0	124,702
1.0	16,330	1.0	45,120	1.0	117,902
1.5	15,850	2.0	38,080	2.0	107,497
1.9	15,800	3.0	31,600	2.5	101,574
1.91	14,250	4.0	26,590	3.0	89,200
2.0	12,750	5.0	22,620	4.0	81,250
2.5	11,250	6.0	18,376	5.0	71,300
3.2	9,750	8.0	12,689	6.0	63,300
3.9	8,770	10.0	11,489	7.0	47,300
4.8	8,030	12.0	10,376	8.0	44,350
5.8	7,380	14.0	9,242	10.0	37,450
5.9	6,990	16.0	8,129	12.0	30,575
7.5	6,975	18.0	7,372	14.0	30,574
8.0	6,650	20.0	6,615	15.0	25,200
9.5	6,050	22.0	5,794	16.0	23,525
10.8	5,300	24.0	5,285	18.0	23,250
10.9	4,100	26.0	4,820	20.0	20,750
12.0	3,700	28.0	4,376	22.0	19,200
13.1	3,500	30.0	4,176	24.0	18,250
15.0	3,450	32.0	3,798	25.0	15,706
17.1	3,300	34.0	3,598	27.0	14,427
19.2	3,000	36.0	3,320	28.0	13,783
21.3	2,500	38.0	3,142	29.0	12,873
21.4	1,850	40.0	3,130	33.0	11,717
25.3	1,815	42.0	3,100	35.0	11,133
29.0	1,785	44.0	3,050	38.5	10,096
33.0	1,710	46.0	3,002	40.0	9,647
37.0	1,550	47.0	2,772	42.0	9,046
42.0	1,330	47.1	0	43.0	8,743
42.1	0			44.0	8,439
				44.1	0

Vehicle Ride Limited Speed (6 Watts Av. Vertical Absorbed Power)
vs. Speed, Data Item #41

M113A1		IFV #1A		IFV #1, #2, #3, #4, #5, #6		
Surface Roughness RMS Inches	Speed, mph	Surface Roughness RMS Inches	Speed, mph	Surface Rougness RMS Inches	Speed, mph	
0	42	0	47	0	47.0 (44.0)	IFV #2, #3, #4, #5, & #6 only
.56	42	.67	47	1.4	47.0 (44.0)	
.57	40	.78	37.8	1.5	47.0 (44.0)	
.67	31.5	1.0	29.0	1.6	47.0 (44.0)	
.78	27.5	1.2	24.7	1.72	40.0	
1.0	23.0	1.3	23.1	2.0	30.7	
1.2	20.3	1.4	21.9	2.5	19.5	
1.3	18.9	1.5	20.8	2.8	14.0	
1.4	17.5	1.6	19.9	3.0	13.0	
1.5	16.7	1.72	19.0	3.5	11.6	
1.6	15.6	2.0	17.0	4.0	10.6	
1.72	14.6	2.5	15.3	5.0	9.3	
2.0	13.0	2.8	14.3	6.0	8.6	
2.5	11.5	3.0	13.9			
2.8	10.8	3.5	12.8			
3.0	10.5	4.0	10.7			
3.5	9.7					
4.0	9.0					

Vehicle Obstacle Impact Limited Speed Vs. Obstacle Vertical
Height, Data Item #42

M113A1		IFV #1A		IFV #1, #2, #3, #4, #5, #6		
Obstacle Vertical Height, inches	Speed, mph	Obstacle Vertical Height, inches	Speed, mph	Obstacle Vertical Height, inches	Speed, mph	
0	42	0	47	0	47.0 (44.0)	
8.3	42	12.3	47	5.0	47.0 (44.0)	IFV #2,
8.5	35	12.5	39	10.0	47.0 (44.0)	#3, #4,
9.0	24.5	13.0	29	12.5	47.0 (44.0)	#5 &
10.0	13.0	14.0	18	12.6	33.0	#6 only.
11.0	7.8	15.0	12	13.0	23.0	
12.0	6.0	16.0	8.5	14.0	15.0	
12.3	5.5	18.0	3.5	15.0	12.5	
12.5	5.2	20.0	1.2	16.0	10.5	
13.0	4.7	30.0	1.1	20.0	8.5	
14.0	3.8	36.0	1.0	25.0	7.6	
15.0	3.0	50.0	1.0	30.0	7.0	
16.0	2.2			35.0	6.7	
18.0	1.5			40.0	6.5	
20.0	1.1			45.0	3.5	
24.0	1.0			49.0	1.0	
50.0	1.0					

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